IX. *The Development of the Pancreas, the Pancreatic and Hepatic Ducts, in* Trichosurus vulpecula.

By Margaret Tribe, *M.Sc.* (*Lond.*), *Percy Macgregor Research Scholar.*

Communicated by Prof. J. P. Hill, *F.R.S.*

(Received June 15, 1916—Read December 7, 1916.)

(From the Embryological Laboratory, Department of Zoology, University of London, University College.)

[Plate 11.]

Contents.

Introduction.

Hitherto no detailed account of the development of the alimentary canal and its associated glands in the Marsupialia has been published. The present paper is the result of an investigation into the development of these structures, in so far as concerns the pancreas, the pancreatic and hepatic ducts in *Trichosurus*.

The material examined belongs to Professor Hill's collection of Marsupials. The embryonic stages are those employed by Fraser and Hill in their paper on the "Development of the Thymus, Epithelial Bodies and Thyroid in the Marsupialia,"* but a considerably larger number of pouch-fœtuses was available for examination. The series ranges from the embryo of greatest length (G.L.) 5 mm. to the pouch-

* 'Phil. Trans.,' B, vol. 207 (1915).

 [Published separately, March 20, 1918.]

fœtus of greatest length 5·2 cm., head length (H.L.) 19·5 mm., and comprises in all twenty-two stages, of which fifteen are embryonic and seven are pouch-young. Reference has also been made to two adult specimens.

For the purposes of accurate investigation, wax-plate reconstructions have been made of the pancreas, pancreatic and hepatic ducts and of the gut related thereto, in five stages. The models of Stages II, III, VIII and XI were constructed at a magnification of 150 diameters, and that of Stage XX at a magnification of 85 diameters. These models are reproduced in Plate 11, figs. 1, 2, 3, 4 and 5, and I take this opportunity of thanking Miss Steele for her beautiful drawings of the same.

I wish to record my gratitude to Prof. J. P. Hill, at whose suggestion the present investigation was undertaken, for the constant help and advice which he has extended to me throughout, and which I have highly valued.

I am also indebted to Prof. G. D. Thane for his kindness in lending me certain periodicals, and to Dr. W. C. Mackenzie for a description of the pancreas and its relations in the adult *Trichosurus*. For help in making the models and for photographing the same I have to thank Mr. F. Pittock, of this Department.

Description of the Course of Events.

1. *Hepatic Ducts and Gall-Bladder.*

(*a*) *Hepatic Ducts.*—The primordium of the liver arises as a median diverticulum of the ventral wall of the entodermal gut tube at the junction of the region of the incipient stomach with the but slightly indicated duodenum; it lies in consequence cranial to the anterior intestinal portal. The primordium in Stage I (embryo δ '97, G.L. 5 mm.) has the form of a small globular appendage of the gut in wide open communication with the same, situated between the large right and smaller left vitelline vein, and prolonged distally and laterally into solid strands of cells constituting the trabeculæ (text-fig. 1 and Plate 11, fig. 1, *h.div.* and *tr.*).

The trabecular strands furnish the liver parenchyma; the proximal part of the primordium, which represents the original hepatic diverticulum, and which may be designated by that name, becomes transformed into the ductus choledocus and hepatic duct, and gives origin to three appendages, the two ventral pancreatic primordia and the cystic primordium. From the latter the cystic duct and the gall-bladder arise.

With progressive development the hepatic diverticulum grows in size and undergoes differentiation. Originally globular in form (Plate 11, fig. 1, *h.div.*), it increases in length and decreases in width to become tubular; its proximal region adjoining the gut persists as the tubular ductus choledochus, its more distal region forms the hepatic duct, while proliferative activity is restricted to the lateral aspects of the intervening portion of the diverticulum and to the hepatic duct (Plate 11, fig. 2).

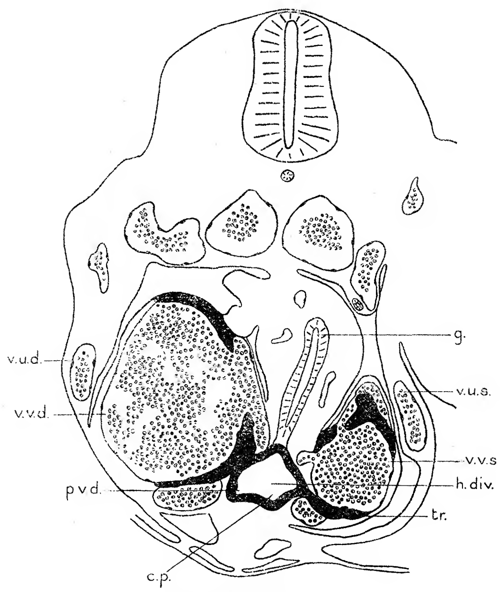
The trabeculæ also become more extensive: no longer limited to the ventral, medial and dorsal aspects of the vitelline veins, they invade and encroach upon the said veins, these latter having meantime themselves undergone marked developmental changes.*

In Stage I (embryo δ '97, G.L. 5 mm.) the trabeculæ arising laterally from the proximal region of the hepatic diverticulum encircle only the medial, lateral, and in part the dorsal walls of the vitelline veins (text-fig. 1, *tr.*), whereas distally a radiating proliferation occurs. As development proceeds, the lateral walls of the diverticulum continue to proliferate, as do also the cells of the trabeculæ themselves, and the strands come to anastomose with one another and at the same time invade the lumen of the vessels, the latter in time undergoing complete conversion into a vascular sinusoidal network. When the portal vein is recognisable as such (Stage III, embryo α '97, G.L. 7 mm.) the trabeculæ, no longer having the form of thick separate strands but branching and anastomosing throughout their course, have extended round and have invaded the right, the ventral and also the dorsal aspects of the spiral vessel, which has resulted from the fusion and subsequent partial degeneration of the originally separate vitelline veins. The trabeculæ thus come to form an almost complete broad peripheral investment to the spiral vessel. As development proceeds the trabeculæ continue to branch and anastomose and to invade the lumen of this vessel until its course is so far interrupted that it assumes the form of a sinusoidal network traversed by the portal vein and by a cranial continuation of the same, this venous trunk representing in the main the persistent portions of the vitelline veins which have not been invaded by hepatic tissue.

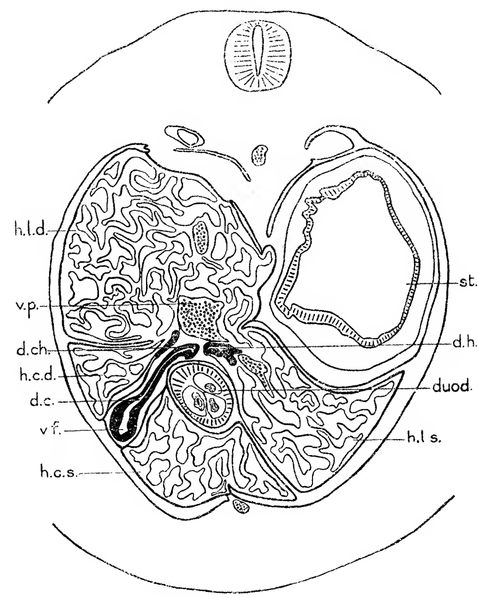
(b) *Gall-bladder.*—The cystic primordium arises as a secondary outgrowth from the ventral wall of the hepatic diverticulum in close proximity to the opening of the latter into the duodenum and very shortly after the origin of the diverticulum itself from the gut. The primordium is just recognisable in Stage I (embryo δ '97, G.L. 5 mm.) as a small depression in the floor of the hepatic diverticulum, approximately median in position (text-fig. 1, *c.p.*). The cells forming its wall undergo rapid division, with the result that in the succeeding stage the primordium appears externally in the form of a minute globular projection from the ventral aspect of the hepatic diverticulum (Plate 11, fig. 1, *c.p.*). With progressive development the primordium grows in length and alters in shape. For a time it retains its original globular form (Plate 11, fig. 2, *c.p.*), but in Stage VI (embryo XX '04, G.L. 7·75 mm.) its cranial or distal segment has begun to increase in diameter, this increase being indicative of the commencing differentiation of the primordium into its cystic and vesicular (gall-bladder) portions. This differentiation is recognisable in Stage VIII, where the primordium is club-shaped (Plate 11, fig. 3, *c.p.*). By Stage X (embryo 4 '99, G.L. 10·25 mm.) there is a sharp demarcation between the two

* The vascular supply of the liver and the development of the same will be described in detail in connection with the development of the liver in a subsequent paper.

portions, the cystic duct being typically tubular, the gall-bladder situated at right angles to the duct and projecting cranio-ventrally (Plate 11, fig. 4, *d.c.* and *v.f.*). The cystic duct at this stage is short, but as development proceeds it elongates, until in Stage XXI it is nearly twice as long as the gall-bladder. The latter here becomes more slender, having grown in cranio-ventral extent and decreased in diameter. The duct arises approximately from the mid-region of the vesicle and is situated at right angles to the long axis of the same (Plate 11, fig. 5, *d.c.* and *v.f.*). In the adult, the gall-bladder is typically pyriform, the cystic duct, which is slender and about the same length as the vesicle, arises approximately at right angles to the same.



TEXT-FIG. 1.



TEXT-FIG. 2.

TEXT-FIG. 1.—Stage I (embryo δ '97, G.L. 5 mm.), Sl. 6–4–12. Transverse section through the hepatic diverticulum (*h.div.*), showing the cystic primordium (*c.p.*), the right ventral pancreas (*p.v.d.*), and the liver trabeculæ (*tr.*). × 37. *c.p.*, cystic primordium; *g.*, gut; *h.div.*, hepatic diverticulum; *p.v.d.*, right ventral pancreas; *tr.*, hepatic trabeculæ; *v.u.d.*, right umbilical vein; *v.u.s.*, left umbilical vein; *v.v.d.*, right vitelline vein; *v.v.s.*, left vitelline vein.

TEXT-FIG. 2.—Stage XIV (embryo XIII '02, G.L. 13·5 mm.), Sl. 19–1–8, 9, 10, and 11. Composite drawing of four transverse sections to show the definitive position of the gall-bladder (*v.f.*). × 18. *d.c.*, ductus cysticus; *d.ch.*, ductus choledochus; *d.h.*, ductus hepaticus; *duod.*, duodenum; *h.c.d.*, right central lobe of liver; *h.c.s.*, left central lobe of liver; *h.l.d.*, right lateral lobe of liver; *h.l.s.*, left lateral lobe of liver; *st.*, stomach; *v.f.*, gall-bladder; *v.p.*, portal vein.

At the time of its first appearance, the cystic primordium is situated approximately in the median plane of the embryo (text-fig. 1, *c.p.*). In the course of development it extends forwards as above noted, partly as the result of the growth and displacement of the hepatic diverticulum, partly and mainly as the result of its own growth, and comes to project cranio-ventrally, running out at the same time towards the right side of the embryo (text-fig. 2, *v.f.*).

The primordium lies at first quite free from hepatic tissue, but as the latter increases in amount, it extends across underneath (ventral to) the cystic primordium. Contemporaneously with the extension of the liver-mass, the cystic primordium becomes elongated, with the result that both cystic and vesicular portions are eventually completely surrounded by hepatic tissue. The gall-bladder lies either quite peripherally in the liver substance or some little distance within the same (text-figs. 2 and 23, *v.f.*); the cystic duct passes over the duodenum first as a straight duct but later becomes curved to accommodate itself to the bend of the gut in this region, marking the site of the junction of the first and second parts of the duodenum (Plate 11, figs. 4 and 5, *d.c.*). As soon as the definitive liver-lobes are recognisable, the gall-bladder and cystic duct are seen to be situated between the left central and the right central lobes (text-fig. 2, *d.c.* and *v.f.*, and text-fig. 23, *v.f.*).

The gall-bladder in *Trichosurus*, it may be noted, never passes through a solid stage in its development. The cystic primordium is luminated at its first origin and the lumen is retained throughout its subsequent development.

2. *Pancreas.*

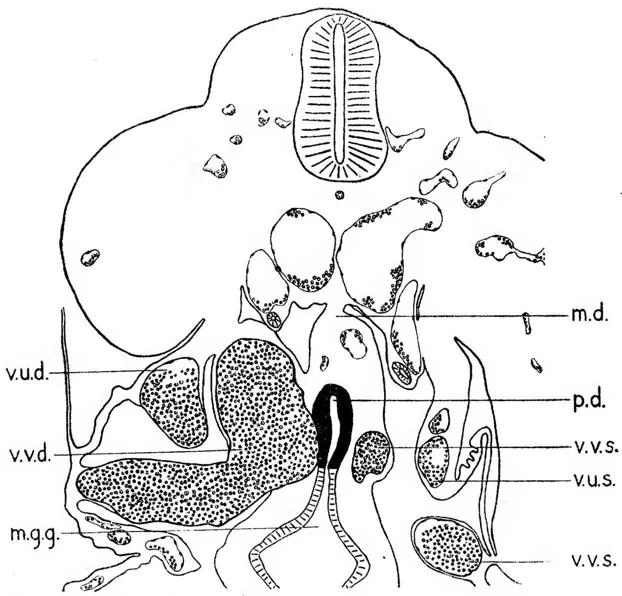
The pancreas in *Trichosurus* is derived from three originally distinct primordia, a dorsal and two ventral, the latter respectively right and left. The dorsal pancreas arises earlier than either ventral pancreas; of the two ventral primordia the right makes its appearance before the left.

(a) *Dorsal Pancreas.*—The dorsal pancreas arises as a diverticulum of the dorsal wall of the mid-gut groove. It lies in consequence caudal both to the anterior intestinal portal and to the hepatic diverticulum, which latter, it will be remembered, lies at the time of its origin cranially to the former.

In Stage I (embryo δ '97, G.L. 5 mm.) the primordium of the dorsal pancreas, very shortly after its first appearance, has the form of an elongated sac-like diverticulum, hollow throughout and communicating with the gut by an extensive opening (text-fig. 3, *p.d.*). The walls of the diverticulum are from the first thicker than those of the adjacent mid-gut, and with progressive development they increase in thickness, the lumen becoming correspondingly narrowed. As early as Stage III (embryo α '97, G.L. 7 mm.) the internal surface of the gland has become irregularly lobed, but it is not until Stage V (embryo II '01, G.L. 6 mm.) that this condition becomes visible externally. From then onwards the gland becomes more and more markedly branched and at the same time alters in shape. It is at first a simple sac-like diverticulum communicating with the gut throughout the greater part of its cranio-caudal extent; but gradually this extensive communication (Plate 11, fig. 1) becomes constricted into a tubular stalk (Plate 11, fig. 2) which, narrowing still further and at the same time lengthening, forms the definitive dorsal pancreatic duct (Plate 11, fig. 3, *d.p.d.*).

Much controversy has arisen on the question of the direction of the process of

constriction undergone by the dorsal pancreas. It has been held that the constriction takes place cranio-caudally, because of the presence of a very deep furrow at the cranial limit of the gland in early stages. Such a furrow is present in *Trichosurus* (Plate 11, figs. 1 and 2, *p.d.* (*f*)), but it must be borne in mind that the furrow may be due, equally well, to subsequent growth of the gland in the cranial direction, as to cranio-caudal constriction of the same. Accurate measurements are the only satisfactory basis on which to base conclusions, and such have accordingly been made at different stages of development in *Trichosurus*, in a manner similar to that employed by HELLY (17) when investigating the same phenomenon in the Rabbit,



TEXT-FIG. 3.—Stage I (embryo ♂ '97, G.L. 5 mm.), Sl. 7–3–2. Transverse section through the early primordium of the dorsal pancreas (*p.d.*) arising from the mid-gut groove (*m.g.g.*). × 33. *m.d.*, dorsal mesentery; *m.g.g.*, mid-gut groove; *p.d.*, dorsal pancreas; *v.u.d.*, right umbilical vein; *v.u.s.*, left umbilical vein; *v.v.d.*, right vitelline vein; *v.v.s.*, left vitelline vein.

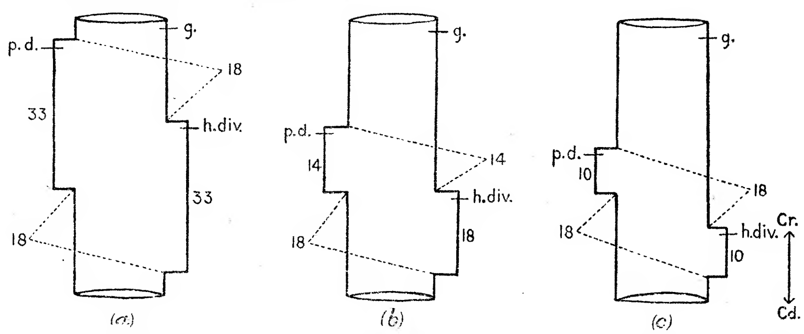
the Guinea-Pig and the Rat. Only wax model reconstructions can be used for this purpose, since measurements based on sections are not reliable, because of the impossibility of making adequate allowance for the sectional plane, which may be very oblique to the organs concerned. Further, it should be noted that distances are measured along the longitudinal axis of the gut-tube and not along the longitudinal axis of the embryo. The section of the duodenum with which we are here concerned, viz., that extending from the cranial limit of the attachment of the dorsal pancreas to the caudal limit of the attachment of the liver primordium, does not grow in length until the apertures of the two organs have come to occupy permanent positions relative to one another. The evidence for this statement will be adduced later, and we pass at once to consider the question of the direction of the constriction-process as elucidated by measurements based on models of the embryos of Stages II, III and

VIII (embryos γ '99, G.L. 5 mm.; α '97, G.L. 7 mm.; XII A '02, G.L. 7·25 mm.). These measurements are appended below in tabular form.

1. Embryo Stage.	2. Length of dorsal pancreatic communication with gut.	3. Length of hepatic communication with gut.	4. Distance between the cranial limit of the dorsal pancreatic primordium and the cranial limit of the hepatic primordium.	5. Distance between the caudal limit of the dorsal pancreatic primordium and the caudal limit of the hepatic primordium.
	mm.	mm.	mm.	mm.
II	33*	33	18	18
III	14	18	14	18
VIII	10	10	18	18

* All measurements are model measurements; if divided by 150 actual measurements are obtained.

These measurements, represented diagrammatically in text-fig. 4, indicate, in the first place, that the distance between the caudal limit of the dorsal pancreatic primordium and the caudal limit of the hepatic primordium remains unchanged (see column 5). It follows therefore, on the one hand, that caudo-cranial constriction of neither organ occurs; or, on the other hand, that both organs undergo caudo-cranial constriction of like amount. As, however, there are no furrows present at the caudal limits of the apertures of the two organs, this latter proposition must be regarded as extremely improbable; we may therefore assume that the caudal limits of the two apertures remain constant in position.



TEXT-FIG. 4.—Diagrams illustrating the direction of the process of constriction of the dorsal pancreas (*p.d.*) and the liver primordium (*h.div.*). (*a*) Stage II (embryo γ '99, G.L. 5 mm); (*b*) Stage III (embryo α '97, G.L. 7 mm.); (*c*) Stage VIII (embryo XII A '02, G.L. 7·25 mm.). *g.*, gut; *h.div.*, hepatic diverticulum; *p.d.*, dorsal pancreas.

Turning now to a comparison of Stages II and III, we see that the distance between the cranial limit of the aperture of the dorsal pancreatic primordium and the cranial limit of the aperture of the hepatic primordium is diminished by 4 mm. (see column 4 : 18 − 14); and the apertures of the two organs into the gut are diminished by 19 mm. and 15 mm. respectively (see columns 2 and 3 : 33 − 14, 33 − 18). As the

caudal limits of the apertures of the two organs may be assumed to be fixed, as stated above, it follows from comparison of these two stages that both organs must have undergone cranio-caudal constriction, the dorsal pancreatic primordium having undergone more constriction than the hepatic primordium, resulting in a diminution of the distance between the cranial limits of the two by 4 mm. as before stated. Comparing now the embryos of Stages III and VIII, we see that the distance between the cranial limits of the apertures of the two organs is increased by 4 mm. (see column 4 : 18—14), while the communications of the two organs with the gut are diminished as before, but to a lesser degree, the decrease in the case of the dorsal pancreas being 4 mm., in the case of the hepatic primordium being 8 mm. (see columns 2 and 3 : 14—10, 18—10). These further changes must be interpreted as being due to a continuation of the constriction-process, but, whereas in the earlier stages the dorsal pancreas underwent the more rapid constriction, the process has here progressed more quickly in the case of the hepatic primordium, to such an extent, indeed, that the aperture of the latter is, in Stage VIII, completely caudal to the aperture of the dorsal pancreas. This position of the aperture of the ductus choledochus almost immediately caudal to the aperture of the dorsal pancreatic duct is permanent until late in fœtal life, for we find similar relations of the two apertures in Stage XX (pouch-fœtus, G.L. 30 mm., H.L. 14 mm.) (Plate 11, fig. 5, *d.p.d.* and *d.ch.*).

By utilising these same measurements we can now seek to prove the contention that the section of the duodenum of which we are treating does not grow in length until the apertures of the two organs have come to occupy permanent positions relative to one another. In the three stages treated of above, we see that the most cranial limit of the gut region in question is constituted in each case by the cranial limit of the dorsal pancreatic aperture (text-fig. 4, (*a*), (*b*), and (*c*)). This cranial limit retreats caudaully, as we have seen, contemporaneously with the cranio-caudal constriction which the aperture of the dorsal pancreas undergoes. The communication of the dorsal pancreas with the gut in Stage II is 33 mm., in Stage III is 14 mm., and in Stage VIII is 10 mm. (see column 2); that is to say, the cranial edge of the communication retreats by 23 mm. (33—10). The caudal limit of the gut concerned is constituted by the caudal limit of the opening of the ductus choledochus into the gut (text-fig. 4, (*a*), (*b*), and (*c*)), and, as we have seen, it is highly probable that this caudal edge retains its original position.

We see, therefore, from the measurements quoted above, that the length of the gut concerned, *i.e.* from the cranial edge of dorsal pancreatic opening to the caudal edge of the aperture of the ductus choledochus, is, in Stage II, 51 mm. (33+18); in Stage III, 32 mm. (14+18); and in Stage VIII, 28 mm. (10+18). We see, further, that the movement in a caudal direction of the cranial edge of the dorsal pancreatic duct is 19 mm. (33—14) in the period of development intervening between Stages II and III, and 23 mm. (33—10) between Stages II and VIII (see column 2). If now

we add, in each embryo, the length of the gut concerned to the amount of constriction undergone by the dorsal pancreas, we find that the result is a constant.

1. Embryo Stage.	2. Length of gut concerned.	3. Constriction undergone by dorsal pancreas.	4. Addition of Columns 2 and 3.
	mm.	mm.	mm.
II	51	Nil	51 + nil = 51
III	32	19	32 + 19 = 51
VIII	28	23	28 + 23 = 51

It is, therefore, justifiable to conclude that the region of gut concerned, *i.e.*, from the cranial edge of the aperture of the more cranial organ to the caudal edge of the more caudal organ, does not grow in length until these processes of constriction have come to an end.

HELLY (17), in treating of the Rabbit, comes to this same conclusion. The growth of this part of the duodenum, according to him, does not take place till the constriction process of the ductus choledochus and of the dorsal pancreatic duct has come to an end. With reference to the Guinea-Pig he goes further and says that it is not until gut rotation has occurred that the various parts of the gut-tube begin to grow in length and thereby cause the further displacement of the openings of the dorsal pancreas and of the ductus choledochus away from one another.

From these measurements and considerations it may be concluded that constriction both of the dorsal pancreas and of the liver primordium takes place in a cranio-caudal direction, and in this manner the original simple sac-like diverticulum, which constitutes the primordium of the dorsal pancreas, becomes differentiated into a glandular portion and a tubular portion or duct. The transition between glandular and tubular regions, at first gradual, becomes more abrupt as development proceeds, the demarcation culminating in a stage where a broad dorsal glandular region is continued ventrally into a narrow tubular duct (Plate 11, fig. 4, *p.d.* and *d.p.d.* (*d.*)). In Stage VI (embryo XX '04, G.L. 7·75 mm.) the glandular portion is distinctly bi-lobed but in the embryos of succeeding stages this appearance is lost, a typically many-lobed gland having arisen therefrom. The transitory bi-lobed condition is therefore but the first sign of the multi-lobular condition of the adult gland. A definite dorsal pancreatic duct is recognisable for the first time in Stage III (embryo α '97, G.L. 7 mm.) from which time onwards the duct decreases markedly in diameter and eventually comes to possess a quite small aperture into the duodenum.

With regard to the persistence of the dorsal pancreatic duct, perfect uniformity obtains up to and including Stage V (embryo II '01, G.L. 6 mm.). Prior to this stage there is always present a perfectly well developed and luminated duct opening by a well marked aperture into the duodenum; subsequently, however, the duct

exhibits a remarkable variability, inasmuch as it may either persist as a luminated tube with a well-marked aperture into the duodenum, or it may degenerate, the lumen becoming occluded and its aperture lost.

It is of interest to note the respective stages at which these two conditions of the duct occur. In the following the duct persists and opens into the duodenum :—

Stage VII (embryo III '01, G.L. 7·25 mm.).
Stage VIII (embryo XII A '02, G.L. 7·25 mm.).
Stage XI (embryo VI '01, G.L. 10 mm.).
Stage XII (embryos XXI '04, G.L. 11 mm., H.L. 6 mm.; XXII '04, 9 '98, 5 '97, G.L. 11·5 mm.).
Stage XIV (embryos VIII '01, G.L. 13 mm.; XIII '02, G.L. 13·5 mm.).
Stage XV (embryos XXIII, G.L. 14 mm., H.L. 6·5 mm.; 4 '99, G.L. 14 mm.).
Stage XVI (pouch-fœtus 5 '97, G.L. 15 mm.; XV '02, G.L. 14·5 mm.).
Stage XVII (pouch-fœtus, G.L. 17 mm., H.L. 7·5 mm.; G.L. 21 mm., H.L. 7 mm.).
Stage XX (pouch-fœtus, G.L. 30 mm., H.L. 14 mm.).
Stage XXII (pouch-fœtus, G.L. 5·2 cm., H.L. 19·5 mm.).

In the following the duct is degenerate and does not possess an aperture into the duodenum :—

Stage VI (embryo XX '04, G.L. 7·75 mm.).
Stage VIII (embryos XII '02, G.L. 7·25 mm.; 6 '98, G.L. 7·5 mm.).
Stage IX (embryo IV '01, G.L. 8·5 mm.).
Stage X (embryo V '01, G.L. 9·5 mm.).
Stage XI (embryo 4 '99, G.L. 10·25 mm.).
Stage XII (embryo VII '01, G.L. 11·5 mm.).
Stage XIV (embryos IX '01, G.L. 13 mm.; XXIV, G.L. 13·5, H.L. 6·25 (two); XXV, G.L. 13 mm., H.L. 6·25 mm.).
Stage XV (embryo XI '01, G.L. 14 mm.; XIV '02, G.L. 14·5 mm.; 4 '97, G.L. 14·75 mm.; 5 '97, G.L. 15 mm.).
Stage XVI (pouch fœtus G.L. 16 mm., H.L. 6·5 mm.; 7 '98, G.L. 15·5 mm.).

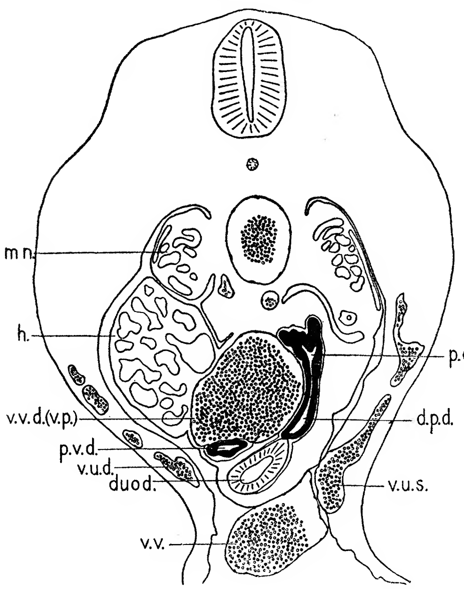
From this survey we see, first, that out of thirty-three embryos and fœtuses the duct persists in seventeen and degenerates in sixteen, and secondly, that the duct may be either present or absent at one and the same stage (*cf.* Stages VIII, XI, XII, XIV, XV and XVI). Neither condition can therefore be regarded as the more general.

The duct, we note, may disappear as early as Stage VI, and it may persist as late as Stage XXII. It is lacking in both the adults that have come under my notice, and so far as I am aware in no adult Marsupial has the existence of a dorsal pancreatic duct been recorded. We may therefore assume from the data given above that there is great variation in the time at which degeneration of the duct occurs.

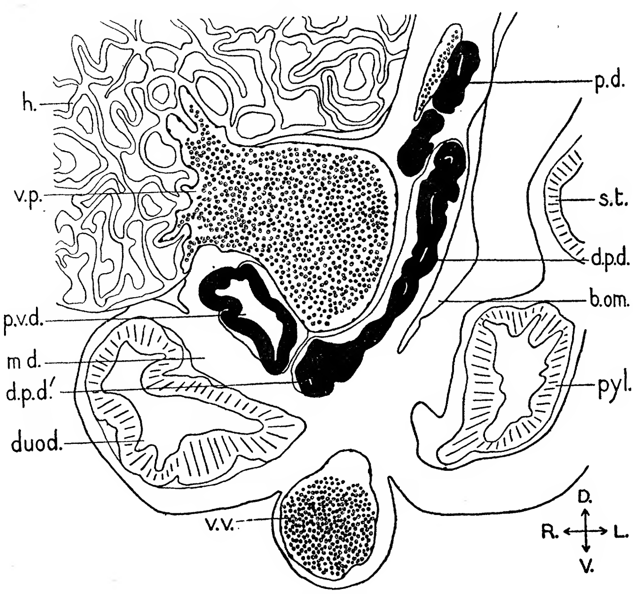
It is probable that before the duct loses its connection with the gut the lumen becomes occluded, for in Stage IV (embryo XIX '04, G.L. 7·5 mm.), immediately preceding the youngest embryo where the duct is blind, the connection of the duct with the gut is solid.

In those cases where the duct disappears, the dorsal pancreas lies for a time perfectly free in the mesentery as an isolated gland, branched and typically alveolar in character (text-fig. 5, *p.d.*). As before mentioned, the time at which the duct degenerates appears to vary within wide limits. It is thus impossible to determine how long the dorsal pancreas lies isolated, but it may be mentioned that Stage VI (embryo XX '04, G.L. 7·75 mm.) is the youngest observed in which the gland has lost its connection with the gut, and Stage X (embryo V '01, G.L. 9·5 mm.) is the youngest in which fusion between the dorsal and right ventral pancreas has been observed to occur. Fusion of the dorsal pancreas with the right ventral pancreas, it may be noted, takes place at the same stage, whether the dorsal duct persists or not.

In early stages the dorsal duct takes a direct course to open into the duodenum, and is of uniform diameter throughout. Immediately prior to the fusion of the



TEXT-FIG. 5.

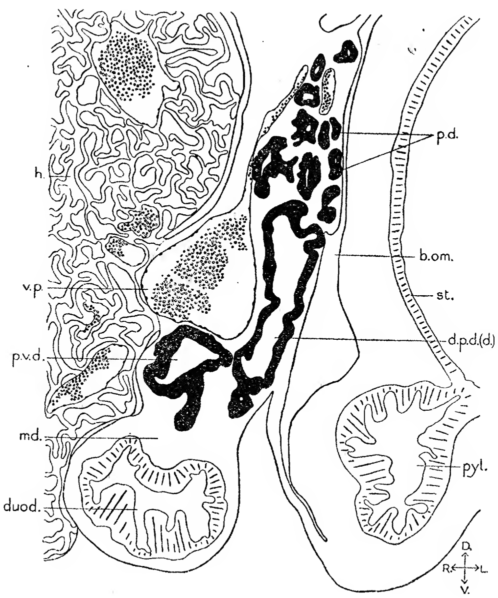


TEXT-FIG. 6.

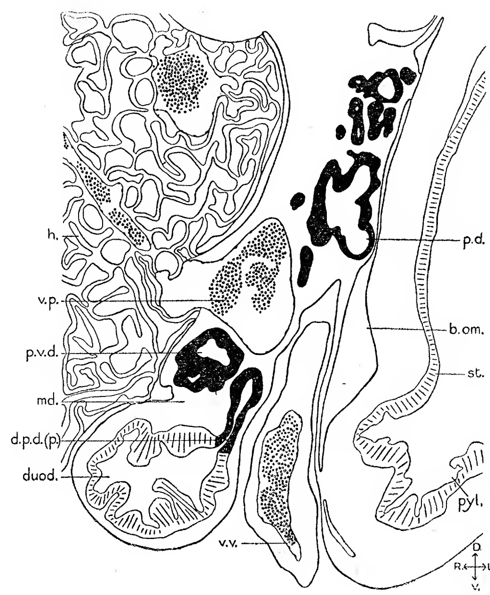
TEXT-FIG. 5.—Stage VI (embryo XX '04, G.L. 7·75 mm.), Sl. 8–5–8. Transverse section showing the isolated dorsal pancreas (*p.d.*). × 26. *d.p.d.*, dorsal pancreatic duct; *duod.*, duodenum; *h.*, liver; *mn.*, kidney; *p.d.*, dorsal pancreas; *p.v.d.*, right ventral pancreas; *v.u.d.*, right umbilical vein; *v.u.s.*, left umbilical vein; *v.v.d.(v.p.)*, right vitelline, future portal, vein; *v.v.*, vitelline vein.

TEXT-FIG. 6.—Stage IX (embryo IV '01, G.L. 8·5 mm.), Sl. 13–5–1. Transverse section showing the incipient branching of the dorsal pancreatic duct (*d.p.d.′*) in the future region of fusion with the right ventral pancreas (*p.v.d.*). × 30. *b.om.*, bursa omentalis; *d.p.d.*, dorsal pancreatic duct; *d.p.d.′*, incipient branching of the dorsal pancreatic duct in the future region of fusion with the ventral pancreas; *duod.*, duodenum; *h.*. liver; *md.*, mesoduodenum; *p.d.*, dorsal pancreas; *p.v.d.*, right ventral pancreas; *pyl.*, pylorus; *st.*, stomach; *v.p.*, portal vein; *v.v.*, vitelline vein.

dorsal pancreas with the ventral pancreas, however, the duct loses its uniform character in the region where fusion will occur and undergoes a conspicuous increase in size, and its walls at the same time become irregular and show signs of incipient branching (text-fig. 6, *d.p.d.'*). The duct, as the result, becomes marked out into two parts, one more dorsal in position adjoining the glandular portion of the organ, which we may term the distal part, the other, or proximal part, more ventral in position and opening into the duodenum, the two being separated by the branched part of the duct in the future region of fusion.



TEXT-FIG. 7.



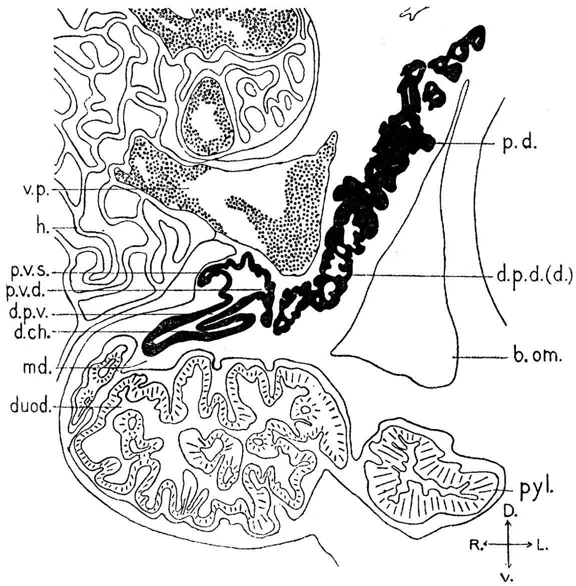
TEXT-FIG. 8.

TEXT-FIG. 7.—Stage XI (embryo VI '01, G.L. 10 mm.), Sl. 16–3–7. Transverse section through the tubular distal part of the dorsal pancreatic duct (*d.p.d.*(*d.*)) encircling the portal vein (*v.p.*). × 50. *b.om.*, bursa omentalis; *d.p.d.*(*d.*), distal region of the dorsal pancreatic duct; *duod.*, duodenum; *h.*, liver; *md.*, mesoduodenum; *p.d.*, dorsal pancreas; *p.v.d.*, right ventral pancreas; *pyl.*, pylorus; *st.*, stomach; *v.p.*, portal vein.

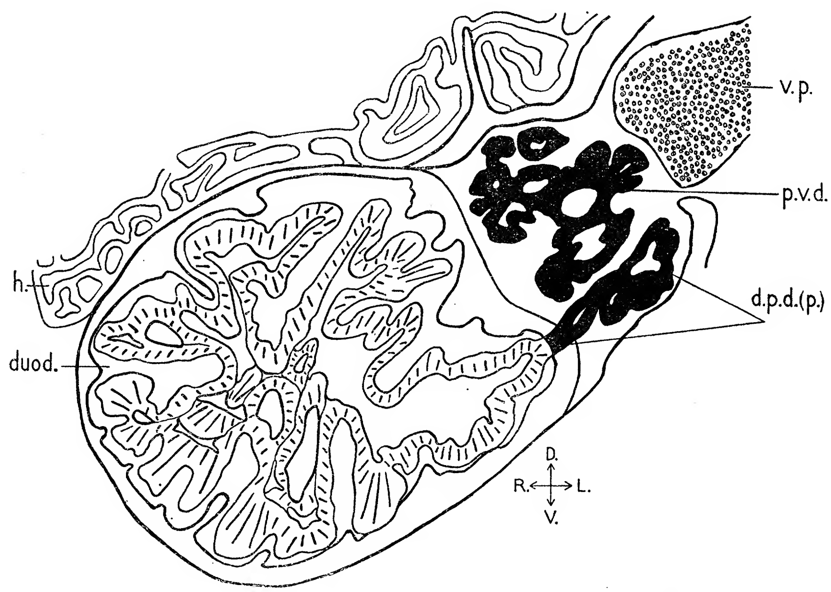
TEXT-FIG. 8.—The same. Sl. 16–4–4. Transverse section through the tubular proximal part of the dorsal pancreatic duct (*d.p.d.*(*p.*)). × 44. *b.om.*, bursa omentalis; *duod.*, duodenum; *d.p.d.*(*p.*)), proximal region of the dorsal pancreatic duct; *h.*, liver; *md.*, mesoduodenum; *p.d.*, dorsal pancreas; *pyl.*, pylorus; *st.*, stomach; *v.p.*, portal vein; *p.v.d.*, right ventral pancreas; *v.v.*, vitelline vein.

Both portions of the duct, distal and proximal, retain their tubular character for a considerable time (text-figs. 7, *d.p.d.*(*d.*), and 8, *d.p.d.*(*p.*)), but finally they undergo marked branching. The distal part ceases to be recognisable as a duct at all and appears simply as the direct continuation of the first formed glandular region of the organ. It encircles the left aspect of the portal vein (text-fig. 9, *d.p.d.*(*d.*)). The major portion of the proximal part also forms glandular tissue, the remainder either degenerates completely or persists; in the latter case it retains its original tubular character and forms the true dorsal pancreatic duct (text-fig. 10, *d.p.d.*(*p.*)).

We see therefore that the distal part of the original duct loses its tubular character entirely and contributes largely to the glandular tissue of the organ, while the



TEXT-FIG. 9.—Stage XII (embryo VII '01, G.L. 11·5 mm.), Sl. 16–2–10. Transverse section through the typically branched distal part of the dorsal pancreatic duct (*d.p.d.*(*d.*)) encircling the portal vein (*v.p.*). × 44. *b.om.*, bursa omentalis; *duod.*, duodenum; *d.ch.*, ductus choledochus; *d.p.d.*(*d.*), distal region of the dorsal pancreatic duct; *d.p.v.*, ventral pancreatic duct; *h.*, liver; *md.*, mesoduodenum; *p.d.*, dorsal pancreas; *p.v.d.*, right ventral pancreas; *p.v.s.*, left ventral pancreas; *pyl.*, pylorus; *v.p.*, portal vein.



TEXT-FIG. 10.—Stage XV (embryo 4 '99, G.L. 14 mm.), Sl. 18–1–5. Transverse section through the proximal part of the dorsal pancreatic duct, in part branched and in part tubular (*d.p.d.*(*p*)). × 75. *d.p.d.*(*p.*), proximal region of the dorsal pancreatic duct; *duod.*, duodenum; *h.*, liver; *p.v.d.*, right ventral pancreas; *v.p.*, portal vein.

proximal part contributes in lesser degree to the glandular tissue and in addition forms the true dorsal pancreatic duct.

(*b*) *Ventral Pancreas*.—The ventral pancreas, as before noted, is of double origin; the two constituent parts differ in the time of their appearance and, as long as they are individually recognisable, in their size, but they arise in a precisely similar manner and each contributes to a greater or lesser extent to the pancreatic tissue of the adult.

In Stage I (embryo δ'97, G.L. 5 mm.) a very minute primordium of the right ventral pancreas only is recognisable; in another embryo of the same stage (embryo 1'01, G.L. 5 mm.), as well as in Stage II (embryo β'98, G.L. 4·5 mm.), two small outgrowths of approximately equal size are present; in another embryo of Stage II (embryo γ'99, G.L. 5 mm.) there is only one outgrowth, the right; in all later stages the two are uniformly present, the right invariably of greater dimensions than the left. These observations indicate, first, a slight variation with regard to the stage at which the primordia appear, and, secondly, a tendency on the part of the right ventral pancreas to appear before the left. This latter fact is of interest in view of the facts, that the right ventral pancreas starts to undergo branching at an earlier stage than the left, and that it develops into a larger gland and contributes more tissue to the adult composite organ than does the left. The conclusion that we have to do here with two distinct primordia admits of no doubt.

The ventral primordia originate as lateral hollow outgrowths of the hepatic diverticulum, close to its origin from the gut. The first primordium of the right ventral pancreas in Stage I (embryo δ'97, G.L. 5 mm.) is seen in transverse section in text-fig. 1 (*p.v.d.*); the two primordia at this same stage (embryo 1'01, G.L. 5 mm.) are seen in transverse section in text-fig. 11 (*p.v.d.* and *p.v.s.*). The right ventral pancreas is visible externally in Stage II (embryo γ'99, G.L. 5 mm.), and is well seen in the model of this embryo in Plate 11, fig. 1 (*p.v.d.*), in the form of a minute lateral outgrowth from the right wall of the hepatic diverticulum, projecting obliquely dorso-laterally.

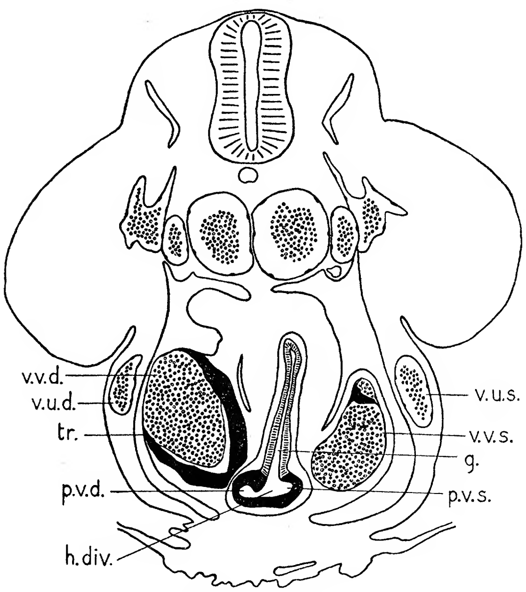
In Stage III (embryo α'97, G.L. 7 mm.) the two primordia are conspicuous structures, clearly seen in the model of this embryo (Plate 11, fig. 2, *p.v.d.* and *p.v.s.*). The left appears as a blunt projection from the corresponding lateral wall of the ductus choledochus; the right outgrowth, situated directly opposite the left, is larger, and has the appearance of a finger-like process coming off laterally from the ductus and stretching out towards the right side of the embryo.

As development proceeds, the two primordia increase in size, the larger right growing more rapidly than the left, with the result that the original difference in size between the two becomes more marked as time goes on (*cf.* Plate 11, figs. 2 and 3, *p.v.d.* and *p.v.s.*).

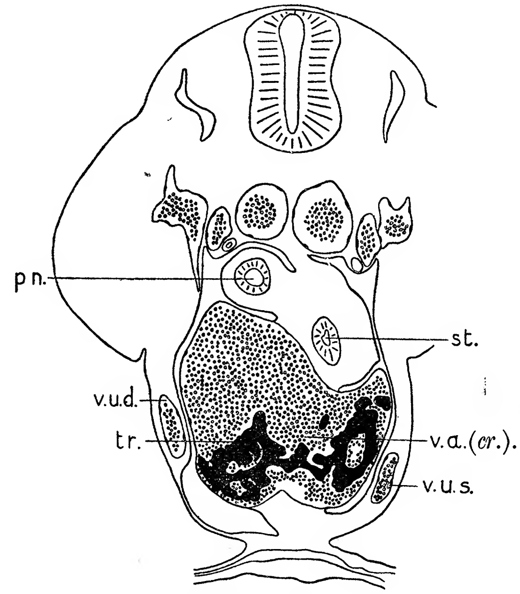
In early stages each outgrowth is bounded by smooth walls (text-fig. 11, *p.v.d.* and *p.v.s.*), but as growth proceeds there soon appear signs of incipient branching.

The right primordium shows irregularities of surface for the first time in Stage VIII (embryo XII A '02, G.L. 7·25 mm.), well shown in Plate 11, fig. 3 (*p.v.d.*), the left has just lost its originally uniformly smooth surface in Stage IX (embryo 5 '97, G.L. 8·5 mm.), while both have assumed a typically branched appearance by Stage XI (embryo 4 '99, G.L. 10·25 mm.). This branching, indicated by irregularities of the surfaces of the primordia, is seen in the model of this stage in Plate 11, fig. 4 (*p.v.d.* and *p.v.s.*).

At the time of their first appearance the three outgrowths of the hepatic diverticulum, viz., the right and left ventral pancreatic primordia and the cystic primordium, are found lying in close proximity to one another. The two former project out laterally from the sides of the diverticulum, but incline somewhat dorsally so that their apices lie laterally to the ventral region of the gut itself, while from the ventral aspect of the diverticulum the cystic primordium projects.



TEXT-FIG. 11.



TEXT-FIG. 12.

TEXT-FIG. 11.—Stage I (embryo 1 '01, G.L. 5 mm.), Sl. 5–3–10. Transverse section through the earliest primordia of the two ventral pancreatic outgrowths (*p.v.d.* and *p.v.s.*); position (1) of the ventral pancreatic primordia. × 37. *g.*, gut; *h.div.*, hepatic diverticulum; *p.v.d.*, right ventral pancreas; *p.v.s.*, left ventral pancreas; *tr.*, hepatic trabeculæ; *v.u.d.*, right umbilical vein; *v.u.s.*, left umbilical vein; *v.v.d.*, right vitelline vein; *v.v.s.*, left vitelline vein.

TEXT-FIG. 12.—Stage II (embryo γ '99, G.L. 5 mm.), Sl. 3–4–4. Transverse section through the cranial (ventral) venous anastomosis *v.a.* (*cr.*)). × 33. *pn.*, lung; *st.*, stomach; *tr.*, hepatic trabeculæ; *v.a.* (*cr.*), cranial (ventral) venous anastomosis; *v.u.d.*, right umbilical vein; *v.u.s.*, left umbilical vein.

Prior to its differentiation into ductus choledochus and hepatic duct, the hepatic diverticulum, as already mentioned, decreases markedly in diameter, and at the same time increases in length, so that from being globular in shape it becomes tubular. As the result the dorsally projecting portions of the ventral pancreatic primordia are

drawn entirely ventral to the gut and the cystic primordium is carried away from the proximal region of the hepatic diverticulum. The ventral pancreatic primordia in this manner take up their positions in the caudal angle between the hepatic diverticulum (ductus choledochus) and the gut, while the cystic primordium is separated therefrom by the intervening portion of the ductus choledochus.

(c) *Fusion and later Development.*—For the proper understanding of the processes whereby the three originally distinct primordia, originating from different regions and different aspects of the entodermal digestive tube, give rise to the single adult pancreas, the original positions of the three primordia in relation to the embryo as a whole, to the gut, to the ductus choledochus, and to the large vessels coursing through the liver must be carefully noted, as also the various alterations in position undergone by the three pancreatic primordia, by the gut and by the ductus choledochus.

Fusion of the three primordia is conditioned (1) by the shifting of the position of the aperture of the ductus choledochus in the gut wall, first in the cranio-caudal, and then later in a right lateral, direction, and (2) by the extension in certain definite directions of all three primordia as the result of increase in size due to their active growth.

At the time when the gut is still approximately straight (Stage I, embryo δ' 97, G.L. 5 mm.) the dorsal pancreas lies over the mid-gut groove, caudal both to the anterior intestinal portal and to the cranial (ventral) anastomosis formed between the vitelline veins, which occurs immediately caudal to the sinus venosus (text-fig. 12, *v.a.* (*cr.*)). The hepatic diverticulum in the same stage lies cranially to the anterior intestinal portal, between it and this cranial (ventral) anastomosis.

Later the dorsal pancreas is found to bear a definite relationship to the middle (dorsal) venous anastomosis which is formed caudally to the cranial (ventral), its free end lying dorsal to this new anastomosis and its opening (future dorsal pancreatic duct) being situated immediately cranial to the same, a relationship which is preserved in succeeding stages (text-fig. 13, *v.a.*(*md.*)). The middle (dorsal) anastomosis occurs for the first time in Stage II (embryo γ '99, G.L. 5 mm.). A further advance is seen in this latter stage, inasmuch as the dorsal pancreas no longer arises from the mid-gut groove, gut-closure having progressed to such an extent that the anterior intestinal portal is now situated caudally to the place of origin of the dorsal pancreas from the gut. Contemporaneously with these changes the aperture of the hepatic diverticulum has shifted its position and has come to lie partly opposite, partly caudal, to the dorsal pancreatic aperture.

It is highly probable, in view of the constant relationship of the dorsal pancreas to the middle (dorsal) venous anastomosis, that the communication of the former with the gut remains stationary throughout its entire development; quite otherwise is it, on the contrary, with the hepatic diverticulum. In earlier stages, as before noted, it borders on the edge of the anterior intestinal portal and is markedly cranial to the dorsal pancreatic aperture, in later stages, it lies cranial to the anterior intestinal portal and

slightly caudal to the dorsal pancreatic aperture. This change in position is undoubtedly brought about by the progressive closure of the gut. Situated on the edge of the anterior intestinal portal, the hepatic diverticulum is carried back with the latter as it travels caudally, until it reaches the region of the dorsal pancreas, which meantime has remained stationary. These relative positions attained to, no further actual movement of apertures of the two structures occurs.

Although the definitive opening of the dorsal pancreas into the duodenum remains stationary from the time of its formation, yet the gland itself undergoes marked shifting in position.

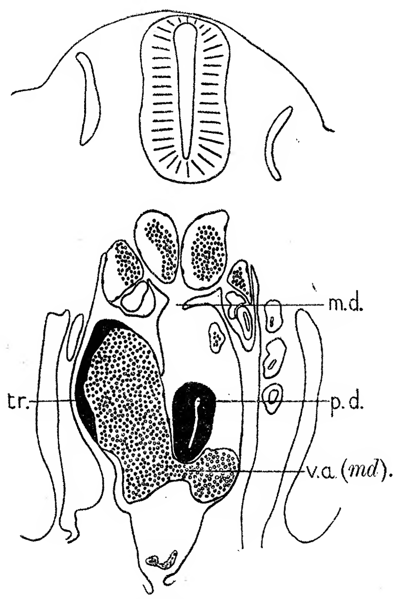
At the time when the primordium of the dorsal pancreas is first recognisable, the mid-gut has undergone very little differentiation indeed. The future stomachal region is just indicated and the mesogastrium, in consequence of the commencing change in position of the stomach, shows signs of a slight degree of displacement towards the left. Behind the stomachal region the duodenum is tubular for only a very short distance and is succeeded by an extensive mid-gut groove in open communication with the yolk-sac.

Owing to the subsequent differentiation of the entodermal tube and related progressive development of the mesenteries and of the various cœlomic cavities, combined with growth of the gland itself, the dorsal pancreas, in the course of its development, comes to occupy a very different position from its original median one.

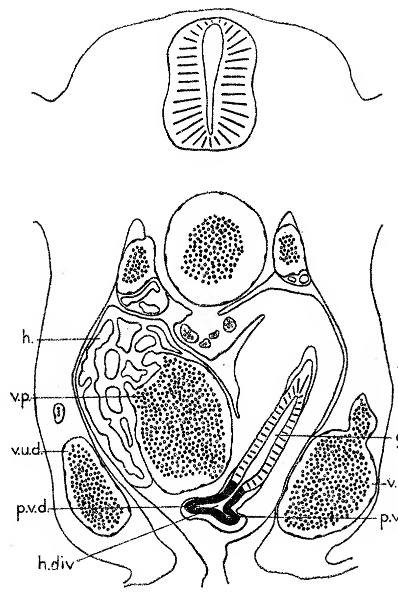
The primary position of the dorsal primordium is shown in text-fig. 3, *p.d.* It is here approximately median, though distally it inclines to the right even in Stage I (embryo δ '97, G.L. 5 mm.) and is situated in the mesoderm of the dorsal mesentery. It lies medially to the two vitelline veins but bears no definite relationship to the future hepatic vessels, for the primordium lies some distance caudal to the cranial (ventral) venous anastomosis and there is at this stage no middle (dorsal) anastomosis. As soon, however, as this latter anastomosis is formed, we note that the gland takes its origin from the gut immediately cranial to this, in other words, the future dorsal pancreatic duct lies between the two vitelline veins of the venous ring which arises as the result of the formation of the two anastomoses referred to above and opens into the gut immediately cranial to the middle (dorsal) venous anastomosis. The glandular tissue, in contradistinction to the duct, lies dorsal to the left half of this cranial venous ring. As the development of the hepatic vessels proceeds, the left limb of this cranial venous ring degenerates, with the result that the dorsal duct now lies on the left of the right half, which will later form part of the definitive portal vein (text-fig. 6, *d.p.d.*). The glandular portion lies dorso-laterally on the left of the future portal vein and also extends to a slight degree along the dorsal aspect of the same.

In course of time, the dorsal mesentery of the gut, in the region of the stomach, becomes deflected to the left, owing to its attachment to the dorsal border of that organ, and constitutes the mesogastrium. The dorsal pancreas lying therein is consequently carried in the same direction, and, in addition, it extends by its own

active growth, still within the limits of the same mesentery, towards the left side of the embryo. The duct passes off from the ventral aspect of the glandular portion of the pancreas, runs obliquely to the right and ventrally, encircling, as in earlier stages, the left aspect of the portal vein.



TEXT-FIG. 13.



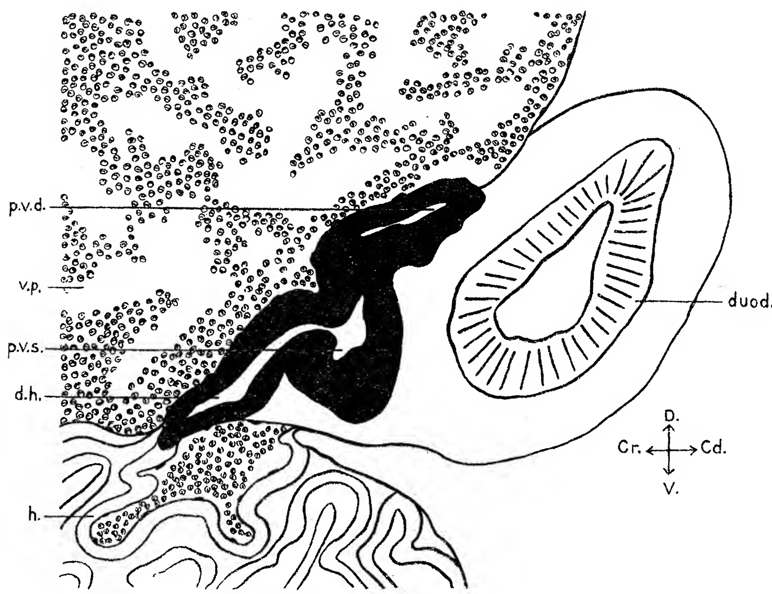
TEXT-FIG. 14.

TEXT-FIG. 13.—The same, Sl. 4–2–3. Transverse section through the middle (dorsal) venous anastomosis (*v.a.* (*md*)). × 33. *m.d.*, dorsal mesentery; *p.d.*, dorsal pancreas; *tr.*, hepatic trabeculæ; *v.a.* (*md*), middle (dorsal) venous anastomosis.

TEXT-FIG. 14.—Stage IV (embryo XIX '04, G.L. 7·5 mm.), Sl. 6–3–8. Transverse section showing position (2) of the ventral pancreatic primordia (*p.v.d.* and *p.v.s.*). × 27. *g.*, gut; *h.*, liver; *h.div.*, hepatic diverticulum; *p.v.d.*, right ventral pancreas; *p.v.s.*, left ventral pancreas; *v.p.*, portal vein; *v.u.d.*, right umbilical vein; *v.u.s.*, left umbilical vein.

To turn now to the ventral pancreas. At the time of their origin, the primordia lie one on each side of the median hepatic diverticulum, each situated towards the medial aspect of the corresponding vitelline vein, at a level immediately caudal to the cranial (ventral) venous anastomosis (text-fig. 11, *p.v.d.* and *p.v.s.*). During the progressive closure of the gut, the hepatic diverticulum, as already described, is carried in a caudal direction, and its appendages, the two ventral pancreatic primordia, are, of course, also involved in this movement, and carried backward. They thus come to lie at the level of the cranial venous ring, immediately cranial to the middle (dorsal) anastomosis, which has meantime been formed. When this ring becomes incomplete, it is to the persisting right limb that they become related (text-fig. 14, *p.v.d.* and *p.v.s.*). The right ventral pancreas lies directly ventral to the right limb (original right vitelline vein) of the cranial venous ring, or, as it may be termed, the portal vein (text-fig. 14, *v.p.*); the left ventral pancreas, on the contrary, lies not beneath the portal vein, but more towards the left side of the embryo, below the position

originally occupied by the left limb (left vitelline vein) of the cranial venous ring. These relations of the two ventral primordia, however, are not retained long, since the opening of the ductus choledochus alters its position, and, from being ventral, comes to be situated on the right lateral wall of the gut. As the result, the two ventral pancreatic primordia now lie ventral to the portal vein, the right immediately below it, the left removed some little distance from the vein, being separated therefrom by the ductus choledochus (text-fig. 15, *p.v.d.* and *p.v.s.*).



TEXT-FIG. 15.—Stage VIII (embryo XII A '02, G.L. 7·25 mm.), Sl. 9-1-6. Longitudinal section showing position (3) of the ventral pancreatic primordia (*p.v.d.* and *p.v.s.*). × 39. *d.h.*, ductus hepaticus; *duod.*, duodenum; *h.*, liver; *p.v.d.*, right ventral pancreas; *p.v.s.*, left ventral pancreas; *v.p.*, portal vein.

We observe, then, three stages in the development of the relations of the ventral pancreatic primordia to the vitelline veins: (1) each primordium lies ventro-medially to the corresponding vitelline vein (text-fig. 11); (2) the right retains its ventro-medial relation to the right vitelline, now portal, vein, but the left, owing to the disappearance of the left vitelline vein in this region, loses its relation to that vessel (text-fig. 14); (3) both right and left primordia become related to the right vitelline, now portal, vein, the former lying ventral to the vein as in earlier stages, the latter having apparently been swung in towards the middle line, so that it, too, lies ventral to the right vitelline, now portal, vein (text-fig. 15). These changes in position may be accounted for, as we shall see later, by the translation of the ductus choledochus referred to above. With progressive development, no further relative alteration in position with regard to the portal vein occurs; the left ventral pancreas persists ventral to the portal vein, separated therefrom by the ductus choledochus and the right ventral pancreas; the right ventral pancreas retains its position directly ventral

to the portal vein, and also grows up and around the right side of the vein, and in time encircles a considerable portion of its right lateral aspect (text-fig. 21, *p.v.d.*).

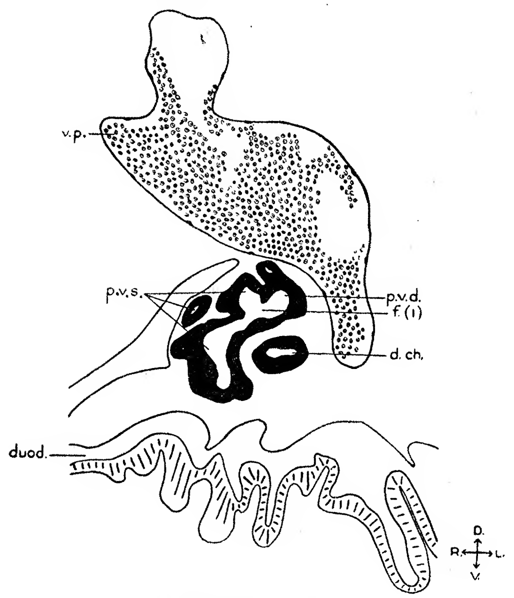
The two ventral pancreatic primordia lie at first in the septum transversum, one on either side of the median ductus choledochus, later (Stage VIII, embryo XII '02, G.L. 7·25 mm.) we find them situated in the small omentum, still approximately median in position, the right extending into the mesoduodenum, and also out towards the right side of the embryo.

As before mentioned, the hepatic diverticulum, although originating from the ventral aspect of the gut, does not retain this position permanently, but apparently travels round the circumference of the gut, thereby relinquishing its original ventral position, first for a right lateral one, and then for a dorso-lateral one, which latter position is that of the aperture of the adult ductus choledochus. This translation of the ductus influences in marked degree the position of related structures, and also affects fusion in general.

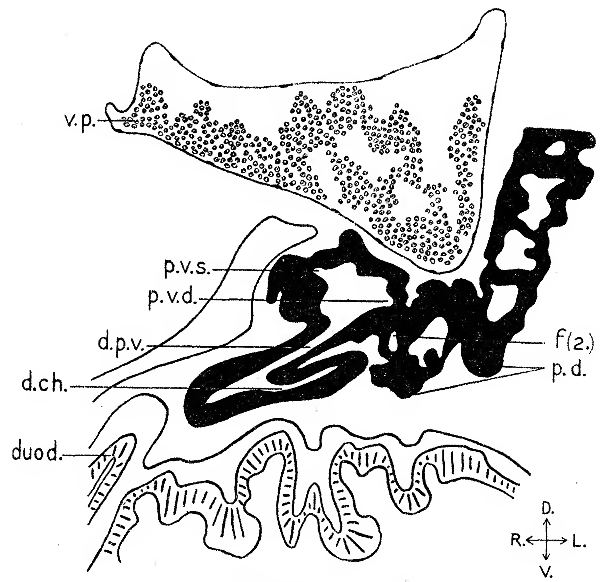
At the time when the aperture of the ductus choledochus is in its primary ventral position, the ventral pancreatic primordia lie lateral thereto and, even when the former has acquired its new position on the right aspect of the duodenum, they retain their former relationship to the ductus, but of course assume a new orientation with reference to the embryo as a whole and to each other. The right now lies dorsally to the left and, whereas originally only the right ventral pancreas lay ventral to the portal vein, the shifting of the ductus choledochus has caused both primordia to rotate, with the result that both come to lie ventral to the portal vein, the left beneath (ventral to) the right. The original lateral surfaces of the ductus choledochus bearing the ventral primordia are now respectively dorsal and ventral, while the right aspect of the right ventral pancreas now faces dorsally, and the left aspect of the left ventral pancreas in a similar manner faces ventrally (text-fig. 20 (1) and (2), and text-figs. 11 and 15). This change is completed in Stage VIII (embryo XII '02, G.L. 7·25 mm.). Subsequently, the ductus choledochus assumes its definitive position, apparently undergoing a further translation, as the result of which its aperture comes to occupy a right dorso-lateral position (text-fig. 20 (3)). This definitive position is acquired at Stage IX (embryo IV '01, G.L. 8·5 mm.), coinciding with the time at which fusion of the pancreatic outgrowths first occurs; indeed, as soon as the ductus has assumed its final position, the three primordia start upon their process of fusion.

As late in embryonal development as Stage VIII (embryo XII '02, G.L. 7·25 mm.), the three primordia are still separate and quite distinct from one another. Let us call to mind the relative positions of the three at the time when fusion sets in. The dorsal pancreas lies mainly in the mesogastrium in the left half of the body of the embryo. It extends ventrally, slightly to the left of the middle line, and encircles in its course the left aspect of the portal vein. It then curls round under the left ventral aspect of the same, where it comes into contact with the ventral

pancreas. The ventral pancreatic tissue, which surrounds the ductus choledochus proximally, lies as a whole in the mesoduodenum, slightly to the right of the middle line; the left ventral pancreas lies ventral to the ductus, the right dorsal thereto. Once these relative positions are attained, fusion rapidly takes place. The first to occur is that between the two ventral primordia on the right dorso-lateral aspect of the proximal part of the ductus, at which place the two enter the ductus together, the point of entrance marking the site of the joint ventral pancreatic duct. This fusion is found to occur for the first time in Stage IX (embryo IV '01, G.L. 8·5 mm.). By Stage X (embryo V '01, G.L. 9·5 mm.) another fusion has taken place dorso-laterally, on the left of the proximal part of the ductus, between the dorsal pancreas



TEXT-FIG. 16.



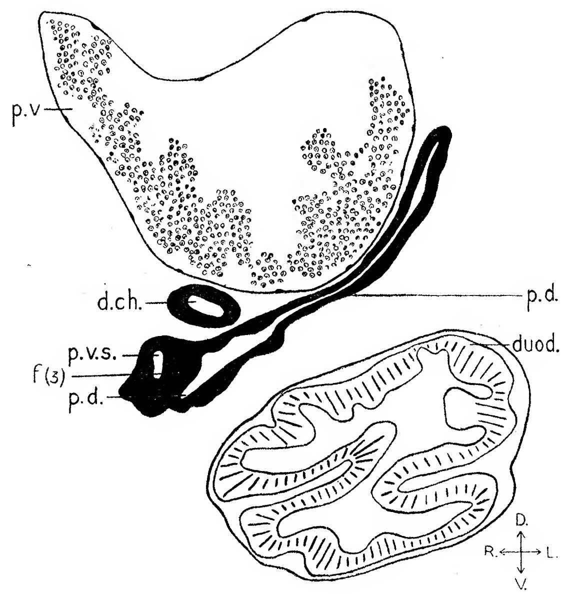
TEXT-FIG. 17.

TEXT-FIG. 16.—Stage XII (embryo VII '01, G.L. 11·5 mm.), Sl. 16–2–3, 4, 5, and 6. Composite drawing of four transverse sections showing fusion (1) of the pancreatic primordia, that between the right and left ventral primordia (*p.v.d.* and *p.v.s.*). × 74. *d.ch.*, ductus choledochus; *duod.*, duodenum; *f.*(1), fusion (1) of the pancreatic primordia, that between the right and left ventral primordia; *p.v.d.*, right ventral pancreas; *p.v.s.*, left ventral pancreas; *v.p.*, portal vein.

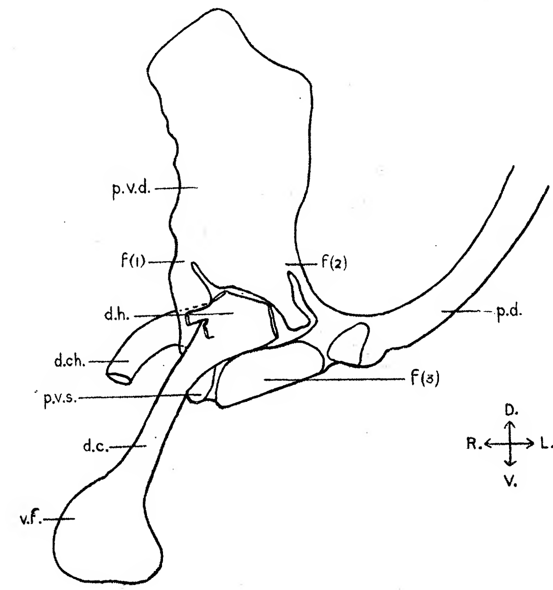
TEXT-FIG. 17.—The same, Sl. 16–2–10 and 15–3–1, 2, 3 and 4. Composite drawing of five transverse sections showing fusion (2) of the pancreatic primordia, that between the dorsal and right ventral primordia (*p.d.* and *p.v.d.*). × 87. *d.ch.*, ductus choledochus; *d.p.v.*, ventral pancreatic duct; *duod.*, duodenum; *f.*(2), fusion (2) of the pancreatic primordia, that between the dorsal and right ventral primordia; *p.d.*, dorsal pancreas; *p.v.d.*, right ventral pancreas; *p.v.s.*, left ventral pancreas; *v.p.*, portal vein.

and the right ventral pancreas. Finally, by Stage XI (embryo IV '99, G.L. 10·25 mm.), fusion has occurred around the left aspect of the proximal part of the ductus, between the dorsal pancreas and the left ventral pancreas. By this series of fusions, successively affecting the three primordia, a complete ring of pancreatic tissue is formed surrounding the proximal end of the ductus choledochus (text-figs. 16, 17, 18, and 19).

It should be borne in mind that the ductus choledochus has already shifted its position before these secondary fusions occur. Fusion between the right ventral pancreas and the left takes place first round the original right *lateral* aspect of the ductus (actual right dorso-lateral). The developmentally succeeding fusion between the right ventral and the dorsal pancreas occurs round the original *right* dorso-lateral aspect of the ductus (actual left dorso-lateral). The third and last fusion, between the left ventral and the dorsal pancreas, which completes the ring, occurs on the original left *dorso*-lateral border of the ductus (actual left).



TEXT-FIG. 18.



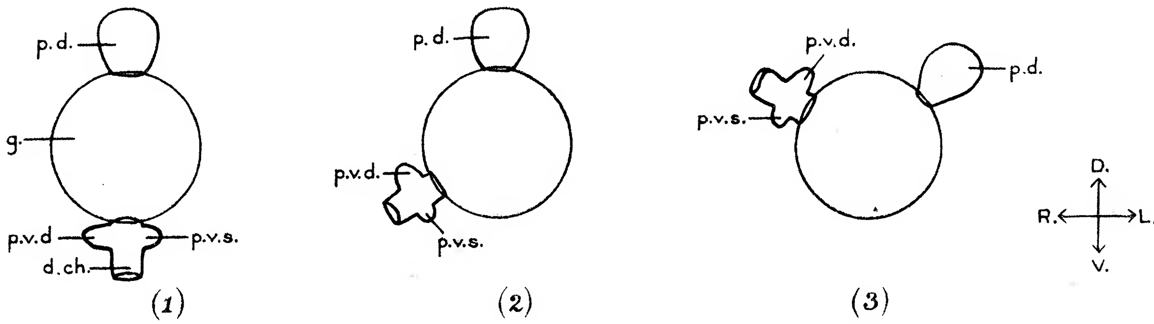
TEXT-FIG. 19.

TEXT-FIG. 18.—Stage XI (embryo 4 '99, G.L. 10·25 mm.), Sl. 11–5–6, 7 and 8. Composite drawing of three transverse sections showing fusion (3) of the pancreatic primordia, that between the dorsal and left ventral primordia (*p.d.* and *p.v.s.*). × 80. *d.ch.*, ductus choledochus; *duod.*, duodenum; *f.*(3), fusion (3) of the pancreatic primordia, that between the dorsal and left ventral primordia; *p.d.*, dorsal pancreas; *p.v.s.*, left ventral pancreas; *p.v.*, portal vein.

TEXT-FIG. 19.—Stage XI (embryo 4 '99, G.L. 10·25 mm.). Diagram of the pancreatic ring, viewed from the cranial aspect. *d.c.*, ductus cysticus; *d.ch.*, ductus choledochus; *d.h.*, ductus hepaticus; *f.*(1), fusion between the right and left ventral pancreas; *f.* (2), fusion between the right ventral and the dorsal pancreas; *f.*(3), fusion between the left ventral and the dorsal pancreas; *p.d.*, dorsal pancreas; *p.v.d.*, right ventral pancreas; *p.v.s.*, left ventral pancreas; *v.f.*, gall-bladder.

We have noted that, at the time of their origin (Stage I, embryo δ '97, G.L. 5 mm.), the apertures of the dorsal pancreas (text-fig. 20 (1), *p.d.*) and of the hepatic diverticulum (text-fig. 20 (1), *d.ch.*) are on opposite sides of the gut, respectively dorsal and ventral. Later (Stage VIII, embryo XII A '02, G.L. 7·25 mm.), although we find the aperture of the dorsal pancreas still dorsal in position, that of the ductus choledochus has come to open approximately into the right lateral aspect of the gut (text-fig. 20 (2)). Whereas, then, in earlier stages the apertures were

separated by one-half the circumference of the gut, *i.e.* by 180°, they are now only separated by one-third of the circumference, *i.e.* by 120°. In all subsequent stages it is found that, although the actual distance between the two apertures remains constant, the two apparently travel in a right to left direction until they come to occupy dorso-lateral positions, the aperture of the dorsal pancreatic duct lying more towards the left side of the dorsal aspect of the gut, the aperture of the ductus more towards the right side (text-fig. 20 (3)).



TEXT-FIG. 20.—Diagrams illustrating the changes in position undergone by the apertures of the dorsal pancreas (*p.d.*) and ductus choledochus (*d.ch.*) and by the ventral pancreatic primordia (*p.v.d.* and *p.v.s.*). *d.ch.*, ductus choledochus; *g.*, gut; *p.d.*, dorsal pancreas; *p.v.d.*, right ventral pancreas; *p.v.s.*, left ventral pancreas.

The means by which these movements are effected are by no means clear. It is evident that rotation of the gut is not of itself sufficient explanatory cause of the movements or apparent movements in question, for the ducts are in such close cranio-caudal proximity to one another that any rotation of the region of the gut in which their apertures are situated would affect both ducts equally and thus could not bring about an approximation of their openings.

Now the movement of the aperture of the ductus choledochus from a ventral to a right lateral position through about 60° is a real and not simply an apparent movement, for, as we have already pointed out, the aperture of the dorsal pancreas remains stationary, whilst the distance between the two apertures undergoes an actual diminution. That being so, one can only suggest that the displacement of the opening of the ductus to the right is due to unequal growth of the gut-wall. Once this initial displacement has been effected, the final positions attained by the ducts may be assumed to be due to rotation of the gut.

It is evident, then, that fusion is ushered in and favoured by the approximation of the aperture of the ductus choledochus to that of the dorsal pancreatic duct. By this approximation, the two appendages of the ductus, the ventral pancreatic primordia, come to lie dorsal and ventral to it, the left at the same time assuming a more median position. The pancreatic primordia are thus brought in close proximity, and fusion soon follows as the result of their active growth and increase in size.

It has been mentioned that the first fusion to occur developmentally is that between the two ventral pancreatic primordia on the right dorso-lateral aspect of the proximal part of the ductus choledochus, here the two primordia enter by a common aperture into the right dorso-lateral (original right lateral) aspect of the ductus, the point of entrance marking the site of the aperture of the ventral pancreatic duct. At the stage, however, when this joint opening first occurs, the two primordia are still quite sessile. In later stages the common ventral pancreatic duct becomes very conspicuous, running dorsal to the proximal part of the ductus choledochus and opening into the same very shortly before the entrance of the latter into the duodenum.

It will be remembered that, primarily, the two ventral pancreatic primordia open into the lateral aspects of the ductus choledochus, on the right and left respectively, being separated from one another medially by the tissue of the ductus. This original position is clearly seen in the models of Stages III (embryo α'97, G.L. 7 mm.) (Plate 11, fig. 2) and VIII (embryo XII A '02, G.L. 7·25 mm.) (Plate 11, fig. 3), while in the model of Stage XI (embryo 4 '99, G.L. 10·25 mm.) we note the occurrence of a joint opening, but so far there is no definite duct (Plate 11, fig. 4).

The original apertures are, then, respectively right and left of the ductus, the common duct ultimately opens into the right dorso-lateral aspect of the same. How does the latter condition arise from the former?

The aperture of the ductus choledochus undergoes a shifting in position from the ventral to the right lateral aspect of the gut. As the result of this movement, the apertures of the two ventral pancreatic primordia suffer no alteration relative to the ductus, but the right pancreas comes to occupy a right dorso-lateral, instead of a right lateral, position, and the left a left ventro-lateral, instead of a left lateral, position. This new position of the right aperture coincides with the site of the common ventral pancreatic duct, which opens into the right dorso-lateral border of the ductus, and, since at no stage has the left ventral pancreas been observed as an isolated structure, we must conclude that the left primordium becomes constricted off from the gut in a left to right direction, in such a way that it comes to open with the right through a common duct. At the time when the joint aperture first appears (Stage XI, embryo 4 '99, G.L. 10·25 mm.), it is remarkably small as compared with the original separate lateral communications of the two primordia with the ductus choledochus.

From the above description of the fusion of the three originally distinct pancreatic primordia, it will be evident that no so-called perivenous ring of pancreatic tissue occurs in *Trichosurus*, for never at any time during ontogeny is the dorsal, or the right dorso-lateral, surface of the portal vein bordered by pancreatic tissue. The remainder of the vein is, however, almost completely enveloped, the dorsal pancreas covering the left aspect, the right ventral pancreas enclosing the major portion of the right as well as the ventral side, and meeting the dorsal pancreas ventrally on

the left. The left ventral pancreas lies some little distance ventral to the portal vein, and does not directly participate in bounding the same (text-fig. 21).

The three pancreatic primordia, at the time of their fusion with one another, are already beginning to undergo a process of branching. The dorsal pancreas and the right ventral pancreas have both lost their simple tubular character at the time when fusion occurs between them, and, although the left ventral pancreas at this stage only shows the slightest indications of branching, by the time that it fuses with the dorsal primordium, it, too, is typically branched.

Fusion, it must be borne in mind, takes place not between the respective ducts of the three primordia, but between actual branched pancreatic tissue. It is true that the branched pancreatic tissue encircling the left aspect of the portal vein is derived from the original dorsal pancreatic duct, but its duct-like structure has entirely disappeared by the time that fusion occurs between it and the two ventral primordia.

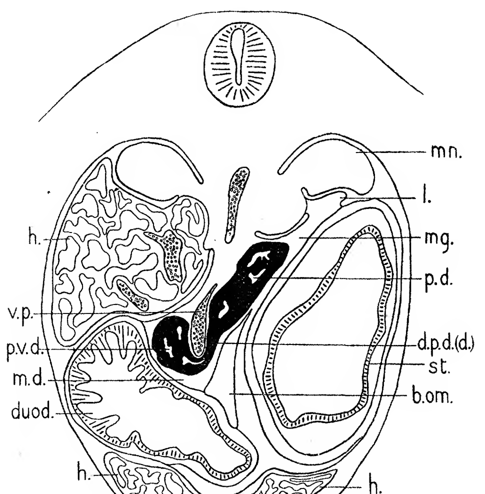
In dealing with the origin and fate of the dorsal pancreatic duct (*ante*, p. 315), attention was called to the fact that the duct exhibits a remarkable variability, inasmuch as it may either persist until late in fœtal life or undergo complete degeneration at a much earlier stage. The duct, when persistent, opens independently into the left dorso-lateral border of the duodenum, removed some little distance from the common bile duct opening. The ventral pancreatic duct, on the contrary, invariably persists. It never at any time opens directly into the duodenum, but only *viâ* the ductus choledochus.

That part of the dorsal pancreatic duct which persists to open into the duodenum is derived from the most proximal region of the original duct (*cf.* text-fig. 10, *d.p.d.*(*p.*)), in other words, from the proximal region of the primary outgrowth from the dorsal wall of the duodenum. The remainder of the original duct, as already stated (*ante*, p. 318), undergoes a marked branching, and becomes indistinguishable from the original alveolar portion of the gland. As the result, the gland for a time lacks a main channel running through it, and possesses instead an extensive system of fine ductules, which open proximally into the short duct where that persists. This condition obtains from Stage XII (embryo XXII '04, G.L. 11·5 mm.), which is the earliest in which the simple tubular character of the duct is lost, to the pouch-fœtus of Stage XX (G.L. 30 mm., H.L. 14 mm.), where a new duct, which I propose to term the secondary dorsal pancreatic duct, is found coursing through that part of the alveolar tissue of the gland which is derived from the distal part of the original duct. This new duct does not, as one might expect, continue on to connect up with the true dorsal duct, but, on the contrary, joins the ventral duct. It appears in cases where the true dorsal duct persists, and in those in which it has degenerated. The late appearance of the duct and its relations show that it is secondary, and of purely functional significance.

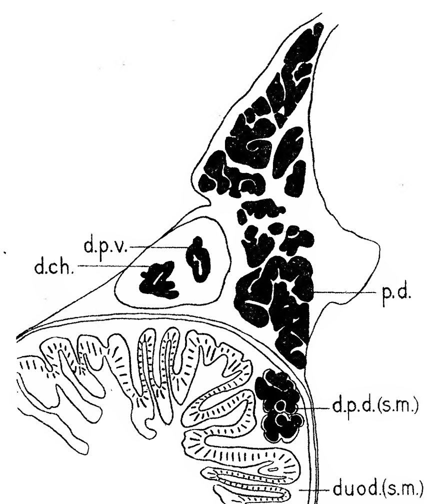
A rather remarkable branching of the dorsal pancreatic duct within the submucosa of the duodenum occurs in some fœtuses. In early embryos the proximal

part of the original dorsal pancreatic duct is tubular throughout its length. Later, a certain portion of this proximal part becomes branched and typically alveolar in character, while the remainder retains its tubular nature and constitutes the true dorsal pancreatic duct. As development proceeds, more and more of this tubular portion undergoes branching, until only that part which actually pierces the duodenal coats retains its duct-like structure. At yet a later stage in development, the tubular character of even the part of the duct piercing the wall of the duodenum may become lost, resulting in the occurrence of the curious condition mentioned above. We find typical glandular tissue piercing the duodenal coats and terminating in a small nodular mass within the sub-mucosa, from which is given off a short tubular duct, which runs in the mucosa to open the apex of one of the valvulæ conniventes. This curious branching of the dorsal pancreatic duct has been found in Stage XX (pouch-fœtus, G.L. 30 mm., H.L. 14 mm.), and Stage XXII (pouch-fœtus, G.L. 5·2 cm., H.L. 19·5 cm.). Text-fig. 22 represents such a sub-mucosal mass in transverse section in the latter pouch-fœtus, while Plate 11, fig. 5, shows the same in the model of the fœtus of 30 mm. (*d.p.d.(s.m.)*).

Another peculiar feature presents itself in *Trichosurus* in the very close cranio-



TEXT-FIG. 21.



TEXT-FIG. 22.

TEXT-FIG. 21.—Stage XIV (embryo XIII '02, G.L. 13·5 mm.) Sl. 19–4–3 and 20–1–1. Composite drawing of two transverse sections demonstrating the incompleteness of the perivenous ring. × 19. *b.om.*, bursa omentalis; *d.p.d.(d.)*, distal region of the dorsal pancreatic duct.; *duod.*, duodenum; *h.*, liver; *l.*, spleen; *md.*, mesoduodenum; *mg.*, mesogastrium; *mn.*, kidney; *st.*, stomach; *p.d.*, dorsal pancreas; *p.v.d.*, right ventral pancreas; *v.p.*, portal vein.

TEXT-FIG. 22.—Stage XXII (pouch-fœtus, G.L. 5·2 cm., H.L. 19·5 mm.), Sl. 21–3–3. Transverse section showing the branched dorsal pancreatic duct (*d.p.d.(s.m.)*) within the sub-mucosa of the duodenum. × 33. *d.ch.*, ductus choledochus; *d.p.d.(s.m.)*, dorsal pancreatic duct branching in the sub-mucosa; *d.p v.*, ventral pancreatic duct; *duod.(s.m.)*, sub-mucosa of the duodenum; *p.d.*, dorsal pancreas.

caudal proximity of the dorsal pancreatic duct to the ductus choledochus. This close proximity is noticeable in the late fœtus (Stage XX, G.L. 30 mm., H.L. 14 mm.) (Plate 11, fig. 5, *d.p.d.* and *d.ch.*). In contradistinction to this condition is that described by the majority of other investigators for the various groups of Vertebrates, where the two apertures in the adult are frequently carried away from one another, often for a very considerable distance, owing to the growth in length of the intervening portion of the duodenum.

Having completed the description of the ontogenetic processes, whereby the three originally distinct pancreatic primordia come to form the single gland, we will now turn our attention to the later development of the same and thence to the adult condition.

Let us call to mind the appearance of the pancreas at the time of fusion as portrayed in the model of Stage XI (embryo 4 '99, G.L. 10·25 mm.), of which Plate 11, fig. 4, represents a right lateral view. Reference may at the same time be made to text-fig. 21, which represents the relations of the pancreas in transverse section, though at a later stage.

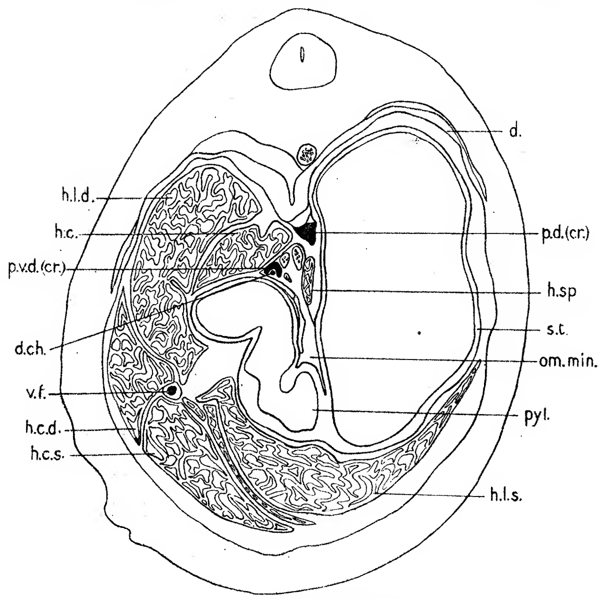
The dorsal pancreas (glandular portion) is here approximately triangular in outline, elongate in the cranio-caudal and dorso-ventral directions, but compressed laterally (Plate 11, fig. 4, *p.d.*). It lies in the mesogastrium (text-fig. 21, *mg.*), and, in consequence, on the left side of the embryo. The glandular portion passes over ventrally into the duct (Plate 11, fig. 4, and text-fig. 21, *d.p.d.*(*d.*)), the latter arising from about its mid-region. The duct, which here still retains its tubular character, runs down ventrally and encircles in its course the left side of the portal vein (text-fig. 21, *v.p.*). Between the glandular portion and the duct on the right, and the stomach on the left, is interposed the omental bursa (text-fig. 21, *b.om.*). The dorsal duct curls round the left ventro-lateral aspect of the portal vein and contributes to the formation of the pancreatic ring by fusing with the left ventral pancreas on the left aspect of the ductus choledochus and with the right ventral pancreas on the left dorso-lateral aspect of the same. The right ventral pancreas borders the dorsal aspect of the ductus, the left ventral pancreas borders the ventral aspect, the ring being completed, as we have seen, by fusion of the two ventral primordia with one another on the right dorso-lateral border of the same (text-fig. 19). The pancreatic ring as a whole lies directly ventral to the portal vein, and is situated in the mesoduodenum (text-fig. 21, *md.*). The right ventral pancreas (Plate 11, fig. 4, and text-fig. 21, *p.v.d.*) extends in a direction caudal to the pancreatic ring and is inclined dorsally, with the result that it encloses on one hand the right aspect of the portal vein, and is applied on the other hand to the beginning of the third part of the duodenum (Plate 11, fig. 4, *duod.*(3)). The openings of the two ventral pancreatic primordia into the duodenum are confluent, the two outgrowths are however as yet sessile, there being no definite duct.

The relations described above are retained for a very considerable period of time. In the pouch-fœtus of Stage XX (G.L. 30 mm., H.L. 14 mm.) although the same

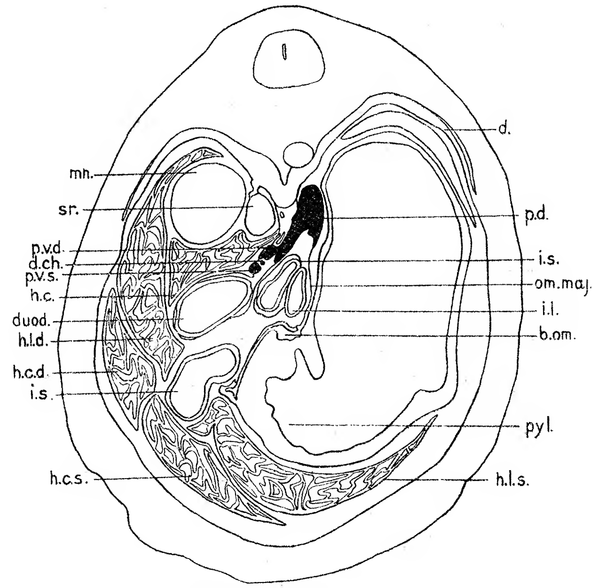
general relations are recognisable, development has progressed to a very marked degree. A right lateral view of the model of this stage appears in Plate 11, fig. 5, transverse sections of the same fœtus are represented in text-figs. 23, 24 and 25. Comparing the models of the two Stages XI and XX (Plate 11, figs. 4 and 5), it should be noted (1) that in Plate 11, fig. 4, the first, second and third parts of the duodenum are represented, but in Plate 11, fig. 5, only the first and part of the second appear; (2) that the second part of the duodenum has grown markedly in length between the two stages, as has also the ductus choledochus and the attendant pancreatic tissue in the same region; (3) that a definitive ventral pancreatic duct is present in the later stage, continuing into the dorsal pancreas as the secondary dorsal pancreatic duct.

In this pouch-fœtus the various component parts of the pancreas are still individually recognisable, although the limits of the original primordia are not so easy to ascertain as in Stage XI. The pancreas has now assumed proportions and relations comparable with the adult gland.

The glandular portion of the dorsal pancreas, which is triangular in shape and



Text-fig. 23.

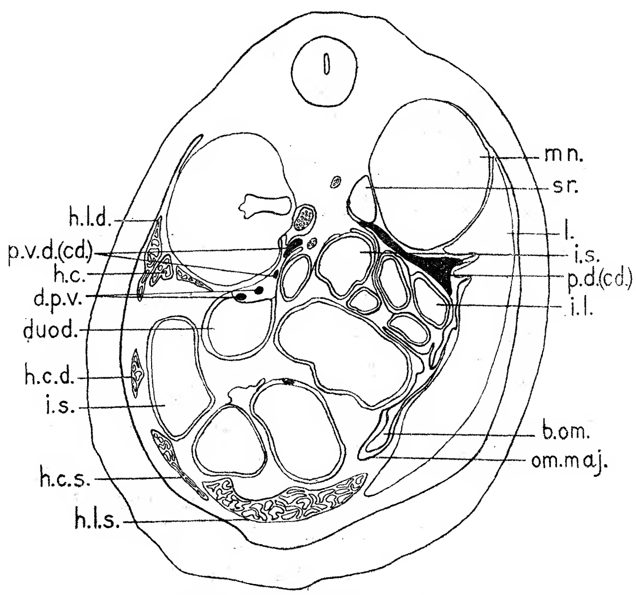


Text-fig. 24.

Text-fig. 23.—Stage XX (pouch-fœtus, G.L. 30 mm., H.L. 14 mm.), Sl. 3–2–4. Transverse section showing the position of the pancreas late in development. × 5. *d.*, diaphragm; *d.ch.*, ductus choledochus; *h.c.*, caudate lobe of liver; *h.c.d.*, right central lobe of liver; *h.c.s.*, left central lobe of liver; *h.l.d.*, right lateral lobe of liver; *h.l.s.*, left lateral lobe of liver; *h.sp.*, spigelian lobe of liver; *om. min.*, small omentum; *p.d.(cr.)*, cranial region of the dorsal pancreas; *p.v.d.(c.r.)*, cranial region of the right ventral pancreas; *pyl.*, pylorus; *st.*, stomach; *v.f.*, gall-bladder.

Text-fig. 24.—The same, Sl. 4–2–4. Transverse section, caudal to text-fig. 23, showing the position of the pancreas late in development. × 5. *b.om.*, bursa omentalis; *d.*, diaphragm; *d.ch.*, ductus choledochus; *duod.*, duodenum; *h.c.*, caudate lobe of liver; *h.c.d.*, right central lobe of liver; *h.c.s.*, left central lobe of liver; *h.l.d.*, right lateral lobe of liver; *h.l.s.*, left lateral lobe of liver; *i.l.*, large intestine; *i.s.*, small intestine; *mn.*, kidney; *om.maj.*, large omentum; *p.d.*, dorsal pancreas; *p.v.d.*, right ventral pancreas; *p.v.s.*, left ventral pancreas; *pyl.*, pylorus; *sr.*, supra-renal body.

markedly compressed laterally in Stage XI, has now assumed large dimensions. Cranially it is still roughly triangular in form and compact in nature (Plate 11, fig. 5, and text-fig. 23, *p.d.*(*cr.*), whereas caudally it is dorso-ventrally compressed and laterally expanded, extending out towards the spleen to come into contact with that organ. This caudal part of the dorsal pancreas is diffuse in nature (Plate 11, fig. 5, and text-fig. 25, *p.d.*(*cd.*)); it seems probable that it is of late origin and owes its existence to the growth of the original glandular portion of the primordium in a caudal direction (*cf.* Plate 11, fig. 4, *p.d.* and fig. 5, *p.d.*(*cr.*) and *p.d.*(*cd.*)). Both cranial and caudal parts of the dorsal pancreas are found to lie in the attachment of the great omentum to the dorsal body wall and are in consequence retro-peritoneal.



TEXT-FIG. 25.—The same, Sl. 7–3–4. Transverse section, caudal to text-fig. 24, showing the position of the pancreas late in development. × 5. *b.om.*, bursa omentalis; *d.p.v.*, ventral pancreatic duct; *duod.*, duodenum; *h.c.*, caudate lobe of liver; *h.c.d.*, right central lobe of liver; *h.c.s.*, left central lobe of liver; *h.l.d.*, right lateral lobe of liver; *h.l.s.*, left lateral lobe of liver; *i.l.*, large intestine; *i.s.*, small intestine; *l.*, spleen; *om.maj.*, large omentum; *mn.*, kidney; *p.d.*(*cd.*), caudal region of the dorsal pancreas; *p.v.d.*(*cd.*), caudal region of the right ventral pancreas; *sr.*, supra-renal body.

The part of the dorsal pancreas just described would seem to correspond to the so-called body of the human pancreas, that portion which extends out towards the spleen representing the so-called tail.

A narrow prolongation from the cranio-ventral region of the dorsal pancreas passes from the fold in which the dorsal pancreas is situated into the mesoduodenum and fuses with the right ventral pancreas situated therein. A continuation of this prolongation passes caudally in the form of a dorso-ventrally elongated and laterally compressed sheet of tissue (Plate 11, fig. 5, *p.d.'*). It borders, in its course, the left aspect of the ductus choledochus, is fused dorso-laterally on the right with the right ventral pancreas, and ventrally with the left ventral pancreas over a very limited

region. From the caudal extremity of this prolongation there is given off a narrow duct which runs ventrally for a short distance, pierces the duodenal wall (descending portion) and opens into the lumen of the same (Plate 11, fig. 5, *d.p.d.*).

The narrow prolongation, above referred to, is the branched representative of the distal part of the original dorsal pancreatic duct; the short duct just described is the persistent tubular portion of the proximal part of the original dorsal pancreatic duct.

The narrow prolongation of the dorsal pancreas and the adjacent part of the right ventral pancreas with which it fuses are together suggestive of the so-called neck of the human gland.

The pancreatic tissue derived from the two ventral primordia lies along the dorsal border of the descending part of the duodenum. It is everywhere compact in character, and in this respect differs from the more caudal portion of the dorsal pancreas.

The right ventral pancreas extends both more cranially and more caudally, and is altogether much larger than the left. It fuses in the mesoduodenum dorso-laterally on the left with the prolongation of the dorsal pancreas and with the continuation of the same, and laterally on the right with the left ventral pancreas. From the region of fusion (Plate 11, fig. 5, *p.v.d.*(*m.*)) it projects cranially into the small omentum as a tongue-like process (Plate 11, fig. 5, and text-fig. 23, *p.v.d.*(*cr.*)) enclosing crescent-like the dorsal and lateral aspects of the ductus choledochus lying in the same fold, while caudally it continues as an elongate club-like process lying dorsal to the ductus in the mesoduodenum (Plate 11, fig. 5, and text-fig. 25, *p.v.d.*(*cd.*)).

The left ventral pancreas (Plate 11, fig. 5, and text-fig. 24, *p.v.s.*) is small and lies ventral to the ductus in the mesoduodenum in the region of fusion of the caudal continuation of the dorsal pancreas with the right ventral pancreas. It gives off a small cranial process which also lies ventrally to the ductus choledochus, while caudally it fuses dorso-laterally on the left over a short distance with the continuation of the prolongation of the dorsal pancreas and laterally on the right over a considerable distance with the right ventral pancreas.

The left ventral pancreas and the right ventral pancreas fuse with the caudal continuation of the dorsal pancreas; consequently here, as in the earlier stages, there is present a pancreatic ring.

The head of the pancreas in Man is constituted by that portion of the gland which is enclosed by the duodenal loop. In *Trichosurus*, however, the ventral pancreas does not extend along much more than half the descending portion of the duodenum and, in consequence, is not related to the loop. The entire ventral pancreas (right and left) and the continuation of the dorsal pancreas caudally to the "neck" together form a mass which recalls the head of the human pancreas.

We have recorded in this pouch-fœtus the existence of the small and very degenerate dorsal pancreatic duct. This, it may be remembered, was lacking in Stage XI. In that stage, also, a differentiated ventral pancreatic duct had not yet been developed, the two pancreatic primordia lying sessile and opening by a common

aperture into the right lateral aspect of the ductus. In the pouch-fœtus of this later stage, however, there is a well-marked common ventral pancreatic duct (Plate 11, fig. 5, and text-fig. 25, *d.p.v.*) running through the ventral pancreas and opening into the ductus choledochus within the duodenal wall, not far from the opening of the ductus.

This ventral pancreatic duct is continued cranially and dorsally into the secondary dorsal pancreatic duct (Plate 11, fig. 5, *d.p.d.(sec.)*), which runs through the glandular prolongation given off from the dorsal pancreas and thence into the dorsal pancreas itself.

If we turn now to the adult, we find approximately the same relations prevailing, although the limits of the various component parts of the pancreas cannot be determined with any degree of accuracy. We may note that the ventral pancreas, as in the pouch-fœtus, does not fill the duodenal loop and that the dorsal pancreas extends out and comes into relation with the small process of the spleen and the lieno-mesocolic fold. Whereas in the pouch-foetus the ventral pancreatic duct opens into the ductus choledochus within the duodenal wall, quite close to the aperture of the latter into the duodenum, in the adult there is a distinct hepato-pancreatic duct, the ventral pancreatic duct opening into the ductus choledochus 1 cm. before the ductus opens into the duodenum. The termination of the ductus is markedly thickened and its opening is situated on a very conspicuous papilla. The dorsal pancreatic duct has not been observed in either of the two adult specimens that have come under my notice.

Summary and Discussion.

Various writers (Brachet, Choronshitzky, etc.) have furnished in recent years more or less detailed *résumés* of the comparative development of the pancreas and hepatic ducts in the various groups of Vertebrates, and to these the reader may be referred. Here I propose to give a summary of my own results and to indicate in what ways the development of these structures in *Trichosurus* agrees with, and differs from, that of other Mammals, so far as these have been investigated.

1. *Origin of the Gall-bladder and Ventral Pancreas.*

In *Trichosurus* the two ventral pancreatic primordia are lateral derivatives, and the cystic primordium is a ventral derivative, of the ductus choledochus (text-fig. 1, *p.v.d.*, *c.p.*, and text-fig. 11, *p.v.d.*, *p.v.s.*).

The question as to whether these primordia are derivatives of the gut-wall proper or of the ductus has been much discussed (Choronshitzky, 3, and Helly, 17). The matter is, however, of no great importance, as the ductus itself is but a differentiated portion of the gut-tube.

The cystic primordium in *Trichosurus* is an unpaired ventral outgrowth from the ductus choledochus. It is luminated at the time of its first origin, and retains a cavity throughout its subsequent development.

In *Echidna*, KEIBEL (24) has observed a paired origin of the gall-bladder primordium, and states, moreover, that in the course of development it passes through a solid stage.

2. *Dorsal Pancreatic Primordium.*

The dorsal pancreas arises in *Trichosurus* as a median dorsal outgrowth of the gut, and communicates with the lumen of the same by a single and at first slit-like aperture (text-fig. 3, and Plate 11, fig. 1, *p.d.*). At the time when the gland is beginning to lose its simple tubular nature and to become secondarily branched, it temporarily assumes a bi-lobed condition. This appearance, however, is transient and is indicative simply of the commencing process of branching, which results in the formation of the definitive alveolar gland.

The unpaired and simple uni-lobed condition of the dorsal pancreatic primordium is of usual occurrence in Mammals (CHORONSHITZKY, 3, and HELLY, 17). A paired origin has, however, been recorded by STOSS (37) in the Sheep and by LEWIS (28) in the Pig. A bi-lobed condition has also been observed in the Rabbit by BRACHET (2), in the Pig by WLASSOW (43), by VÖLKER (40), and also by LEWIS (28). LEWIS, however, finds the bi-lobed appearance restricted to the region of the aperture of the duct into the duodenum.

We have shown (*ante*, p. 311 *et seq.*) that in *Trichosurus* the dorsal pancreas has at first an elongated slit-like communication with the gut, and that during development this opening undergoes constriction, with the result that the gland comes to communicate with the gut by a narrow tubular duct only. The evidence brought forward further shows that the process of constriction in *Trichosurus* takes place in a cranio-caudal direction. In all the other Mammals investigated up to the present time, however, the process is described as beginning at the caudal end of the primordium and progressing in a caudo-cranial direction. The Sheep, however, is an exception, for although the process begins in a caudo-cranial, it progresses in a cranio-caudal direction (CHORONSHITZKY, 3, and STOSS, 37). CHORONSHITZKY (3) definitely states that in Mammals the constriction is caudo-cranial, and this is the view put forward by the majority of investigators: STOSS (37) in the Sheep, VÖLKER (40) in the Pig and Marmot, FELIX (8), HELLY (17), and LEWIS (29) probably, in the human embryo, whereas in all other Vertebrates, according to CHORONSHITZKY (3), it is cranio-caudal.

The question of the direction of the constriction of the dorsal pancreas is intimately bound up with that of the relative positions of the apertures of the dorsal pancreas and ductus choledochus.

In *Trichosurus* the primary position of the aperture of the dorsal pancreatic primordium is markedly caudal to that of the hepatic diverticulum. Then, as the result of gut-closure, the hepatic diverticulum is carried backwards until the aperture of the dorsal pancreas lies partly cranial to, and partly opposite, the aperture of the hepatic

diverticulum. Subsequent alterations in position are caused not by actual movement but by differences in the rate of constriction affecting the two apertures, as a consequence of which the dorsal pancreatic aperture assumes a position immediately cranial to that of the hepatic diverticulum, but later lies some little distance cranial to the same. This cranial position of the dorsal duct persists up to Stage XX (G.L. 30 mm., H.L. 14 mm.), which is the oldest pouch-fœtus in which the duct is recognisable (Plate 11, fig. 5, *d.p.d.* and *d.ch.*). That the apertures lie in such close cranio-caudal proximity to one another at so late a stage is noteworthy, for displacement of the ducts away from one another, as the result of the growth of the intervening portion of the duodenum, appears to be of almost universal occurrence in the Mammalia. It would appear, then, that the definitive dorsal duct remains stationary from the time of its first establishment whilst the ductus choledochus shifts its position.

In Echidna, KEIBEL (24) finds the dorsal duct first cranial, then caudal, and subsequently again cranial to the ductus. As to the cranial adult position of the dorsal duct, KEIBEL is supported by OWEN (32) and by OPPEL (31).

In the Rabbit, Pig and Cat, BRACHET (2) and THYNG (39) record the position of the dorsal duct, at the time of its origin, approximately opposite that of the hepatic diverticulum, its later and adult position caudal thereto.

In the human embryo HELLY (15, 16, 17, 18 and 19) and THYNG (39) state that the dorsal duct occupies a position cranial to the ductus choledochus throughout the entire developmental history of the embryo, as well as in the adult. Movement of the dorsal duct never occurs, according to HELLY. VÖLKER (40 and 41), on the contrary, finds first a caudal, then an opposite and finally the cranial adult position. The dorsal duct and the ductus choledochus move in opposite directions, according to VÖLKER.

We have pointed out (p. 317) that in *Trichosurus*, in those embryos where the dorsal duct degenerates, the dorsal pancreas itself lies for an appreciable time free within the mesentery prior to its anastomosis with the ventral pancreas (text-fig. 5, *p.d.*). There appears to be no parallel to this isolation amongst Mammals, although GÖPPERT (11) records the same occurrence in Teleosts.

3. *Ventral Pancreatic Primordia.*

The ventral pancreas in *Trichosurus* arises from two primordia, a right and a left (text-fig. 11, *p.v.d.* and *p.v.s.*). The right appears slightly before the left and undergoes branching at an earlier stage. Both furnish tissue to the adult gland, the right, which is throughout of greater dimensions, contributing about four times as much as the left.

With regard to the number and fate of the pancreatic primordia in the Amniota, we find much variation. Investigators, indeed, even when dealing with the same animal, do not come to harmonious conclusions.

Amongst the Reptilia, HOFFMANN (21), referring to the group as a whole, denies

the occurrence of a ventral primordium. BRACHET (2) finds two primordia in *Lacerta muralis*, while VÖLKER (40) in *Lacerta agilis* fails to find any ventral pancreas at all. SAINT REMY (36) records two in *Coluber*, as also does JANOSIK (23).

Amongst Birds, GOETTE (10), DUVAL (6) and FELIX (8) record two in the Chick. In *Larus* and *Sterna*, HAMMAR (14) finds only one.

To turn to Mammals. KEIBEL (24) in *Echidna* records two. In the Pig, WLASSOW (43) finds a single primordium divided into two lobes, LEWIS (28) finds a paired primordium, whilst THYNG (39), VÖLKER (40), and HELLY (17) record only one ventral pancreas. STOSS (37) in the Sheep finds two. VÖLKER (40) in the Marmot records the complete absence of any ventral pancreas. In the Rabbit, HAMMAR (14) records only one primordium, BRACHET (1) also finds one, but he regards it as paired in origin, while THYNG (39) finds two lobes arising from a common stem which he regards as indicative of a paired origin. In the Guinea-pig, HELLY (17) finds the ventral pancreas of paired origin, while in the Rat he simply records the presence of a ventral primordium. In the Cat, FELIX (8) and THYNG (39) find one ventral pancreas, while HELLY (17) finds two. In the Dog, HAMMAR (14) records a single primordium. Finally in the human embryo, the earlier investigators contented themselves with determining the presence or absence of the ventral pancreas, with its possible duplicity they did not concern themselves. The presence of a ventral primordium is recorded by PHISALIX (33), ZIMMERMANN (44), HAMBURGER (12), SWAEN (38), KÖLLIKER (25) and HIS (20). ENDRES (7) on the contrary, denies its presence. According to FELIX (8) and JANKELOWITZ (22) there are two, while THYNG (39) finds only a single ventral pancreas.

In *Trichosurus* we have shown that, although there are two ventral pancreatic primordia, they do not both contribute in equal measure to the adult gland. In this respect many other Amniotes resemble *Trichosurus*. In *Lacerta muralis*, BRACHET (1) says the left primordium degenerates entirely and furnishes no pancreatic tissue. In the Rabbit, according to BRACHET (1), the right part only of the fused primordium undergoes progressive development. In the Pig (LEWIS, 28) variation occurs; in some embryos the right only remains, in others both persist, the right being the larger; in yet other embryos the right is rudimentary.

We may conclude then, from these rather contradictory statements, that in Reptiles and Birds two primordia occur as a rule, that in Monotremes (*Echidna*) there are two, in Marsupials (*Trichosurus*) there are two of unequal size, and that in the higher Mammals there is much variation as to the number, the two in Man being of such unequal size that one of them has frequently been overlooked altogether.

4. *Fusion of the Pancreatic Primordia.*

Fusion of the three primordia in *Trichosurus* is conditioned by (1) the shifting of the position of the aperture of the ductus choledochus in the ventral gut-wall, first in a cranio-caudal, and then later in a right lateral, direction, and (2) by the

extension in certain definite directions of all three primordia as the result of increase in size due to their active growth.

The cranio-caudal movement of the aperture of the ductus is brought about by the progressive closure of the gut; the subsequent displacement of the opening to the right is, in all probability, due to unequal growth of the gut-wall in that region. By means of the former movement the aperture of the ductus assumes a position almost opposite that of the dorsal pancreas, the latter results in an approximation of the two by an apparent diminution of the lateral gut-wall situated between them. The dorsal and the two ventral primordia are thus brought into close proximity, and fusion of the three soon follows. The right ventral pancreas fuses dorso-laterally on the left with the branched dorsal pancreatic duct and dorso-laterally on the right with the left ventral pancreas; the left has meantime grown dorsally round the sides of the ductus and fuses dorso-laterally on the right, as before mentioned, with the right primordium and on the left with the branched dorsal pancreatic duct.

It should be noted, in this connection, that the apparent displacement of the apertures of the dorsal pancreas and of the ductus is effected before fusion occurs. This apparent movement may be assumed to be due to rotation of the gut. It does not influence fusion in any way, as the apertures are now in such close cranio-caudal proximity that rotation affects both equally and therefore cannot bring about any relative alterations in their positions.

The causes underlying fusion are apparently so obscure that few investigators have attempted to inquire into them.

GÖPPERT (11), basing his conclusions on the literature concerning the development of the pancreas in Vertebrates up to his time, concludes that fusion of the two ventral primordia is due to their close proximity, but that fusion of the dorsal with the ventral pancreas occurs as the result of the movement of the ductus from a ventral to a right lateral position.

With reference to Reptiles, RATHKE (34) and CHORONSHITZKY (3) state that the aperture of the dorsal pancreas moves from a dorsal, to a right lateral, and thence to a ventral, position, and comes into contact with that of the ductus, fusion of the two apertures resulting. RATHKE regards this movement of the dorsal pancreatic duct as due to the diminution of the right gut-wall. CHORONSHITZKY considers that it is related to gastro-duodenal rotation and torsion of the gut-wall, which latter causes contraction of the gut-wall between the two openings, until such time as the apertures come into contact and fuse. The right ventral pancreas, according to him, bends dorsally and fuses with the dorsal pancreas, the left bends round the dorsal border of the ductus and fuses with the already united dorsal and right ventral pancreas.

In the Sheep, CHORONSHITZKY (3) considers that gut-rotation causes the dorsal pancreatic aperture to open into the left of the duodenum, and the ductus

choledochus and united ventral pancreatic primordia into the right. He states that in Vertebrates, with the exception of Reptiles, the dorsal pancreas usually grows to the right and ventrally, and the right ventral pancreas, as the result of the movement of the ductus caused by gut-rotation, is displaced dorsally, fusion occurring between the blind ends of the two glands.

HELLY (17), drawing his conclusions from his investigations on the Rabbit, Rat, Guinea-pig, Cat, Pig, and Man, postulates in Mammals a mechanical cause working from without, viz., rotation, and, in addition, certain biological properties located in the pancreatic cells themselves.

KEIBEL (24), in *Echidna*, states that, whereas fusion of the dorsal and right ventral pancreas is favoured by the growth of the dorsal pancreas towards the right, the approximation of the two apertures is caused by the growth and change in position of the stomach and duodenum.

BRACHET (2), in the Rabbit, puts forward the opinion that the ductus comes to open into the right aspect of the gut as the result of gastro-duodenal rotation.

THYNG (39), in the Pig, Cat, Rabbit, and human embryos, regards fusion as due to two causes: (1) the actual growth of the dorsal pancreas, resulting in the formation of a ventral process, which runs down on the right of the vitelline vein and fuses with the ventral pancreas; and (2) the development of the duodenal loop and gut-rotation, causing the dorsal pancreas to fuse with the ventral pancreas ventral to the portal vein.

The direction of growth, combined with the place of fusion of the pancreatic primordia determines the presence or absence of the so-called pancreatic and perivenous rings.

A pancreatic ring, *i.e.*, a complete enclosure of the proximal region of the ductus choledochus by pancreatic tissue, occurs in *Trichosurus*. All three primordia participate in its formation (text-fig. 19). The right ventral pancreas borders the dorsal aspect, the left ventral pancreas encloses the ventral and right lateral aspects, the dorsal pancreas and the left ventral pancreas together encircle the left aspect, of the ductus. The ring is completed by the three fusions (1) between the two ventral primordia, dorso-laterally on the right; (2) between the right ventral and the dorsal primordia dorso-laterally on the left; and (3) between the left ventral and the dorsal primordia, laterally on the left.

The existence of a pancreatic ring in *Trichosurus* is remarkable, in that its occurrence has not been recorded as yet in any other Mammal. Amongst lower Vertebrates, however, it seems to be generally present. GÖPPERT (11) and LAGUESSE (26) record it in Fishes, CHORONSHITZKY (3) finds it in Amphibia, CHORONSHITZKY (3) and RATHKE (34) both record it in Reptiles. In the Fishes and Amphibia the two ventral primordia alone contribute tissue to the ring, but in the Reptilia the dorsal pancreas also participates in its formation. In all other

Vertebrates, including Mammals, the existence of a pancreatic ring is either denied or not recorded by investigators.

A perivenous ring, *i.e.*, a complete enclosure of the portal vein by pancreatic tissue, does not occur in *Trichosurus*. It is peculiar that, whereas a pancreatic ring is found in *Trichosurus* and in no other Mammal, yet a perivenous ring, found only in Mammals, and of almost universal occurrence there, does not exist in *Trichosurus*.

The dorsal pancreas, in *Trichosurus*, borders the left aspect of the portal vein, the right ventral pancreas encloses the ventral aspect and the greater part of the right aspect of the same, the dorsal aspect being devoid of pancreatic tissue. The left ventral pancreas does not participate in bounding the vein (text-fig. 21).

KEIBEL (24) does not refer to a perivenous ring in *Echidna*, but, from his illustrations, one is perhaps justified in concluding that it occurs, and that it is constituted by tissue derived from all three primordia. The dorsal pancreas apparently lies across the dorsal aspect of the vein, and projects ventrally to enclose its left lateral aspect, dorsal and right ventral primordia fuse on the right, while the ventral aspect of the vein is bounded by the two ventral primordia. KEIBEL makes no statement with regard to fusion between the dorsal and ventral pancreas ventro-laterally on the left, which would make the ring complete.

HELLY (17) records a perivenous ring in the Rat.

In the Rabbit also it is invariably present, according to BRACHET (2), HELLY (17), and THYNG (39), the two former, however, derive it entirely from dorsal pancreatic tissue, whereas THYNG carefully describes its formation from all three primordia. According to him the dorsal pancreas reaches the dorsal wall of the vitelline (portal) vein and fuses with the ventral pancreas on the right of this vein, while the dorsal pancreatic duct fuses with the ventral pancreas on the median side of the latter.

THYNG (39) finds in the Cat a perivenous ring occasionally in the adult and then it is constituted by tissue from the three primordia. In the Pig, the same conditions obtain as in the Rabbit, while in Man he finds the ring invariably absent.

The existence of accessory pancreases appears to be of not uncommon occurrence in Mammals. In *Trichosurus* in Stage VII (embryo III '01, G.L. 7·25 mm.) a small intestinal diverticulum arising from the proximal part of the duodenum was noticed and in the pouch-fœtus of Stage XVIII (G.L. 21 mm., H.L. 9 mm.) a small globular mass of alveolar tissue, typically pancreatic in character, was observed in the mesoderm surrounding the gall-bladder. According to LEWIS and THYNG (30), such intestinal diverticula and similar outgrowths occurring along the cystic and bile ducts are the probable source of accessory pancreases. WEBER (42) on the contrary, regards them as due to the isolation of portions of an already differentiated pancreatic gland.

It has been held that the shape of the pancreas determines in some measure the the formation of the duodenal loop (*cf. e.g.*, FRASER and ROBBINS, 9). The gland in *Trichosurus*, as we have seen, is of irregular shape, the result perhaps of its assuming

its adult proportions in relation to the growth and development of adjacent structures. It seems improbable that the gland should exert an influence sufficient to cause such a definite formation as the duodenal loop. In this connection, moreover, it may be noted that in *Trichosurus* the pancreas by no means fills the duodenal loop, extending not more than half way along the descending limb of the same, but the loop itself is less well developed than in Man.

5. *The Definitive Pancreatic Ducts.*

The history of the pancreatic ducts in *Trichosurus* may be divided into three developmental periods :—

(1) *Stages I–XII.*—The dorsal pancreas communicates with the gut by a continuous duct. The two ventral primordia open separately and laterally into the ductus choledochus.

(2) *Stages XII–XX.*—The larger part of the original dorsal pancreatic duct (as seen, *e.g.*, in text-fig. 9, *d.p.d.*(*d.*)) has now undergone branching to form pancreatic tubules indistinguishable from the first-formed alveolar part of the gland, and is consequently no longer recognisable as a definite duct. In those cases where the opening of the dorsal pancreas into the duodenum persists, the proximal segment of the duct remains intact (text-fig. 10, *d.p.d.*(*p.*)), but in those cases where the aperture is lost, this proximal segment has, in greater part, disappeared. The two ventral primordia have now acquired a common opening into the ductus, but do not as yet possess a definite duct.

(3) *Stage XX onwards.*—In Stage XX a well-defined duct, which we have termed the secondary dorsal pancreatic duct, is recognisable, extending for some distance into the alveolar part of the dorsal pancreas and continuous proximally with the common ventral pancreatic duct which has now been established (Plate 11, fig. 5, *d.p.d.*(*sec.*) and *d.p.v.*).

Conditions similar to those found in *Trichosurus* have been described by Corner (4) in the Pig. He has shown that at an early period in development the pancreas consists of a plexus of tubules which is connected with the intestine by a narrow duct (the dorsal pancreatic duct) no more capacious than any other tubule of the network. Later a channel is formed by dilatation of the capillary ducts in the primitive plexus, as the result of the hydrostatic necessity for a passage-way for the secretion passing through the plexus. It is extremely probable that the duct in *Trichosurus*, which I have termed the secondary dorsal pancreatic duct, arises in very much the same way.

The earliest embryo in which Corner describes the existence of such a plexus is one of G.L. 35 mm., and he terms the plexus a "primitive plexus." It is more probable, however, that this stage corresponds to the second developmental period of the ducts in *Trichosurus*, and is not a primitive but a secondary and intermediate

stage. This duct of CORNER's is continuous with the dorsal duct which is the only one present in the adult Pig.

In the human pancreas there is a certain amount of variation with regard to the definitive ducts. According to LEWIS (29) and SOBOTTA (35) there are generally two ducts. The "pancreatic duct," or duct of Wirsung, opens into the ductus choledochus, and is formed by the secondary union of the ventral pancreatic duct with the elongated distal portion of the dorsal pancreatic duct. The short proximal segment of the latter remains in continuity with the elongated distal segment and persists as the so-called "accessory duct," or duct of Santorini, which opens directly into the duodenum.

Applying the interpretations and conclusions arrived at by the study of the development of the ducts in *Trichosurus*, supported by CORNER's work on the Pig, it seems at least possible that the elongated distal portion of the original dorsal pancreatic duct in Man is neither more nor less than a secondary duct developing later than any other portion of the ducts, at the expense probably of a tubular network. If this be so, that part of the "pancreatic duct" distal to the place of anastomosis of the "accessory duct" with the "pancreatic duct" in Man should be termed the "secondary dorsal pancreatic duct." It differs, however, in its relations as compared with the Pig and *Trichosurus*. In the former, the secondary duct is continuous with the dorsal pancreatic duct only, there being no ventral pancreatic duct in the adult. In the latter, it connects up with the ventral pancreatic duct, the presence of the dorsal duct in the adult being as yet undetermined. In Man, the secondary duct connects up with both the dorsal and the ventral duct. The "accessory duct" in Man is, of course, the persistent proximal part of the original dorsal pancreatic duct.

In connection with the interesting fact that in *Trichosurus* the dorsal pancreatic duct may or may not persist in the late fœtus, it is of importance to note the developmental and adult conditions in other Amniotes.

In the Reptilia, only one duct persists in the adult; investigators differ, however, concerning its origin. VÖLKER (40), in *Lacerta agilis*, finds the dorsal duct bound up with the ductus choledochus; HAMMAR (14), also in the Lizard, finds a duct formed by the fusion of the dorsal with the ventral duct; CHORONSHITZKY (3), in *Anguis*, derives it from the two ventral ducts and the dorsal duct.

In Birds, CHORONSHITZKY (3) finds all three ducts opening separately in the adult.

In the Monotremata, KEIBEL (24) in *Echidna* finds two ducts, the ventral opening into the ductus choledochus, the dorsal opening separately. OWEN (32), OPPEL (31) and LECHE (27) find only the dorsal pancreatic duct. LECHE (27) in *Ornithorhynchus* records only the ventral pancreatic duct.

In the Marsupialia, OWEN (32) and LECHE (27) refer only to the ventral duct, as also does CUNNINGHAM (5) in *Cuscus* and *Thylacinus*.

Amongst Eutheria, VÖLKER (40) in the Marmot, finds the dorsal duct only, both in

the embryo and the adult. HELLY (17) states that in the Rat there is no aperture belonging exclusively to either the dorsal or the ventral pancreas. In the remaining Eutheria both ducts invariably occur in the embryo, one or both of which may be retained in the adult.

The dorsal duct alone persists in the adult in the Pig (THYNG, 39; GÖPPERT, 11; STOSS, 37; VÖLKER, 40; and WLASSOW, 43), in the Cow (GÖPPERT, 11, and STOSS, 37) and in the Guinea-pig (HELLY, 17). Both ducts persist in the adult in the the Horse and Dog (STOSS, 37), and in the Cat (THYNG, 39).

In the Sheep, STOSS (37) says that the dorsal duct generally degenerates but persists sometimes in the adult. In the Rabbit, THYNG (39) says the dorsal duct always persists, sometimes there are both; BRACHET (2) says both persist generally, the ventral being small; HELLY (17) says very frequently, but not always, there are both.

In Man, as before mentioned, there is some variation with regard to the definitive ducts. The persistence of both ducts is regarded by LEWIS (29) and SOBOTTA (35) as the general condition. According to HAMBURGER (12) this arrangement is constant. The most common variations that may occur, according to SOBOTTA, are (1) an occluded dorsal duct, (2) the complete absence of the dorsal duct (according to STOSS (37) and FELIX (8) this arrangement is constant), and (3) the failure of the secondary union between the two ducts. Variations which may occur occasionally are (1) the respective sizes of the two ducts may undergo reversion, (2) the ventral duct as well as the dorsal may open independently into the duodenum, and (3) the dorsal duct may open *viâ* the ductus choledochus. The ventral duct may be exceptionally absent (THYNG, 39).

With regard to the sub-mucosal pancreas occasionally found in the late fœtus of *Trichosurus* and derived from the branching of the proximal part of the dorsal pancreatic duct within this layer of the duodenal wall (text-fig. 22, and Plate 11, fig. 5, *d.p.d.(s.m.)*, LEWIS (29) and HELLY (16) state that branched tissue derived from the dorsal pancreatic duct is often found in the sub-mucosa of the duodenum in the human embryo.

BIBLIOGRAPHY.

1. BRACHET, A. "Die Entwickelung und Histogenese der Leber und des Pankreas," 'Ergebnisse d. Anat. u. Entw.,' vol. 6 (1896).
2. *Idem.* "Recherches sur le Développement du Pancréas et du Foie (Selaciens, Reptiles, Mammifères)," 'Journ. de l'Anat. et de la Phys.,' vol. 32 (1896).
3. CHORONSHITZKY, B. "Die Entstehung der Milz, Leber, Gallenblase, Bauchspeicheldrüse und des Pfortadersystems bei den verschiedenen Abteilungen der Wirbeltiere," 'Anat. Hefte,' vol. 13 (1900).

4. CORNER, G. W. "The Structural Unit and Growth of the Pancreas of the Pig," 'Amer. Journ. Anat.,' vol. 16 (1914).

5. CUNNINGHAM, D. J. "Some Points in the Anatomy of the Thylacine, Cuscus and Phascogale," 'Challenger Reports,' vol. 5 (1882).

6. DUVAL, M. 'Atlas d'Embryologie,' Paris, 1889.

7. ENDRES, H. "Anatomisch-entwicklungsgeschichtliche Studien über die formbildende Bedeutung des Blutgefäss-Apparates," 'Archiv f. Mikr. Anat.,' vol. 40 (1892).

8. FELIX, W. "Zur Leber- und Pankreasentwickelung," "Arch. f. Anat. und Entw.' (1892).

9. FRASER, J. F., and ROBBINS, R. H. "On the Factors concerned in causing Rotation of the Intestine in Man," 'Journ. of Anat. and Phys.,' vol. 11, (1915).

10. GOETTE, A. "Beiträge zur Entwickelungsgeschichte des Darmkanals im Hühnchen," Tübingen, 1867 (quoted by BRACHET, 1).

11. GÖPPERT, E. "Die Entwicklung des Pankreas der Teleostier," 'Morph. Jahr.,' vol. 20 (1893).

12. HAMBURGER, O. "Zur Entwickelung der Bauchspeicheldrüse des Menschen," 'Anat. Anz.,' vol. 7 (1892).

13. HAMMAR, J. A. "Einige Plattenmodelle zur Beleuchtung der früheren Embryonalen Leberentwickelung," 'Arch. f. Anat. u. Entw.' (1893).

14. *Idem.* "Ueber einige Hauptzüge der ersten Embryonalen Leberentwickelung" and "Einiges über die Duplicität der Ventralen Pankreasanlage," 'Anat. Anz.,' vol. 13 (1897).

15. HELLY, K. "Beitrag zur Anatomie des Pankreas und seiner Ausführungsgänge," 'Arch. f. Mikr. Anat.,' vol. 32 (1898).

16. *Idem.* "Zur Entwicklungsgeschichte der Pankreasanlagen und Duodenalpapillen des Menschen," 'Arch. f. Mikr. Anat.,' vol. 56 (1900).

17. *Idem.* "Zur Pankreasentwicklung der Säugethiere," 'Arch. f. Mikr. Anat.,' vol. 57 (1901).

18. *Idem.* "Bemerkungen zum Aufsatz VÖLKERS: Beiträge zur Entwicklung des Pancreas bei den Amnioten," 'Arch. f. Mikr. Anat.,' vol. 60 (1902).

19. *Idem.* "Zur Frage der primären Lagebeziehungen bei den Pankreasanlagen des Menschen," 'Arch. f. Mikr. Anat.,' vol. 63 (1904).

20. HIS, W. 'Anatomie menschlicher Embryonen,' 1880–1885 (quoted by BRACHET, 1).

21. HOFFMANN, C. K. "Reptilien," BRONN'S 'Klassen und Ordnungen des Thierreichs,' vol. 6, Abth. 3 (1890).

22. JANKELOWITZ, A. "Ein junger Menschlicher Embryo und die Entwicklung des Pankreas bei demselben," 'Arch. f. Mikr. Anat.,' vol. 46 (1895).

23. JANOSIK, J. "Le Pancréas et la Rate," 'Bibliographie Anatomique' (1895) (quoted by BRACHET, 1).

24. KEIBEL, F. "Zur Entwicklung der Leber, des Pankreas und der Milz bei *Echidna aculeata* var. *typica*," SEMON'S 'Forschungsreisen,' III, 2 Theil, 1904.

25. KÖLLIKER, A. 'Entwicklungsgeschichte des Menschen und der höheren Tiere,' 2 Auflage (1879) (quoted by BRACHET, 1).

26. LAGUESSE, E. "Dével. du Pancréas chez les Poissons osseux," 'Journ. de l'Anat. et de la Phys.,' vol. 30 (1894).

27. LECHE, W. "Säugethiere," BRONN'S 'Klassen und Ordnungen des Thier-reichs,' vol. 6, Abth. 5 (1900).

28. LEWIS, F. T. "The bi-lobed Form of the Ventral Pancreas in Mammals," 'Amer. Journ. of Anat.,' vol. 12 (1911).

29. *Idem.* "The Development of the Pancreas," in KEIBEL and MALL'S 'Manual of Human Embryology,' vol. 2 (1912).

30. LEWIS, F. T., and THYNG, F. W. "The Regular Occurrence of Intestinal Diverticula in Embryos of the Pig, Rabbit and Man," 'Amer. Journ. of Anat.,' vol. 7 (1908).

31. OPPEL, A. 'Lehrbuch der vergleichen. mikroskopischen Anatomie der Wirbelthiere,' vol. 3 (1900) (quoted by KEIBEL, 25).

32. OWEN, R. 'The Anatomy of Vertebrates,' vol. 3, "Mammals," London, 1898.

33. PHISALIX, C. "Etude d'un Embryo humain (10 mm.)," 'Arch. de Zoologie Expér.,' Ser. 2, vol. 6 (1888).

34. RATHKE, H. 'Entwickelungsgesch. d. Natter (*Coluber natrix*),' Königsberg, 1839 (quoted by CHORONSHITZKY, 3).

35. SOBOTTA, J. "Anatomie der Bauchspeicheldrüse," in KARL VON BARDELEBEN'S 'Handbuch der Anatomie des Menschen,' Jena, 1914.

36. SAINT-REMY, G. "Recherches sur le Développement du Pancréas chez les Reptiles," 'Journ. de l'Anat. et de la Phys.' (1893).

37. STOSS, A. "Zur Entwickelungsgeschichte des Pankreas," 'Anat. Anz.,' vol. 6, (1891).

38. SWAEN, A. "Recherches sur le Développement du Foie, du Tube digestive, de l'Arrièrecavite du Péritoine et du Mésentère.—Part II," 'Journ. de l'Anat. et Phys.,' vol. 33 (1897).

39. THYNG, F. W. "Models of the Pancreas in Embryos of the Pig, Rabbit, Cat and Man," 'Amer. Journ. of Anat.,' vol. 7 (1908).

40. VÖLKER, O. "Beiträge zur Entwicklung des Pankreas bei den Amnioten," 'Arch. f. Mikr. Anat.,' vol. 59 (1902).

41. *Idem.* "Über die Verlagerung der Mündung des dorsalen Pankreas bei dem Menschen," 'Arch. f. Mikr. Anat.,' vol. 62 (1903).

42. WEBER, J. A. "L'Origine des Glandes annexes de l'Intestine moyen chez les Vertébrés," Thèse, Paris, 1903.

43. WLASSOW. "Zur Entwickelung des Pankreas beim Schwein," 'Morph. Arbeiten,' vol. 4 (1895) (quoted by LEWIS, 29).

44. ZIMMERMANN, K. W. "Rekonstruktion eines menschlichen Embryo," 'Verhandl. d. Anatom. Gesell.' (1889).

DESCRIPTION OF PLATE.

REFERENCE LETTERS COMMON TO THE VARIOUS FIGURES.

a.i.p.	Anterior intestinal portal.
c.p.	Cystic primordium.
d.c.	Cystic duct.
d.ch.	Ductus choledochus.
d.h.	Hepatic duct.
d.p.d.	Dorsal pancreatic duct.
d.p.d.(d.)	Distal region of the dorsal pancreatic duct.
d.p.d.(sec.)	Secondary dorsal pancreatic duct.
d.p.v.	Ventral pancreatic duct.
d.p.d.(s.m.)	Branching dorsal pancreatic duct in the sub-mucosa.
duod.	Duodenum.
duod.(1)	First part of the duodenum.
duod.(2)	Second part of the duodenum.
duod.(3)	Third part of the duodenum.
f.(1)	Fusion between the right and left ventral pancreas.
h.div.	Hepatic diverticulum.
œs.	Œsophagus.
p.d.	Dorsal pancreas.
p.d.(f.)	Furrow at the cranial limit of the dorsal pancreas.
p.v.d.	Right ventral pancreas.
p.v.s.	Left ventral pancreas.
st.	Stomach.
tr.	Hepatic trabeculæ.
v.f.	Gall-bladder.

PLATE 11.

Fig. 1.—Stage II (embryo γ'99, G.L. 5 mm.). Right lateral view of model, showing the dorsal pancreas and the hepato-pancreatic complex. There is no left ventral pancreas at this stage. The aperture of the dorsal pancreas is dorsal, that of the hepatic diverticulum is directly opposite and ventral in position. $\times 50$.

Fig. 2.—Stage III (embryo α '97, G.L. 7 mm.). Right lateral view of model. The left ventral pancreas is now present in addition to the right. The apertures of the dorsal pancreas and hepatic diverticulum have retained their primary positions. × 50.

Fig. 3.—Stage VIII (embryo XII A '02, G.L. 7·25 mm.). Right lateral view of model. The aperture of the ductus choledochus has shifted its position through 60° and now opens laterally into the duodenum. × 50.

Fig. 4.—Stage XI (embryo 4 '99, G.L. 10·25 mm.). Right lateral view of model. Fusion has now occurred, resulting in a complete pancreatic ring surrounding the ductus. The ductus choledochus now opens dorso-laterally into the duodenum. No dorsal pancreatic duct is present here. × 50.

Fig. 5.—Stage XX (Pouch-fœtus, G.L. 30 mm., H.L. 14 mm.). Right lateral view of model. The dorsal pancreatic duct and the ductus choledochus open dorso-laterally into the duodenum. A definitive ventral pancreatic duct is here present, in addition to which the secondary duct is recognisable. (Some pancreatic tissue and part of the wall of the gut have been removed to expose the ducts.) × 21. *p.d.'*, caudal prolongation of the dorsal pancreas on the left of the ductus choledochus; *p.d.(cr.)*, cranial region of the dorsal pancreas; *p.d.(cd.)*, caudal region of the dorsal pancreas; *p.v.d.(cr.)*, cranial region of the right ventral pancreas; *p.v.d.(cd.)*, caudal region of the right ventral pancreas; *p.v.d.(m.)*, middle region of the right ventral pancreas.

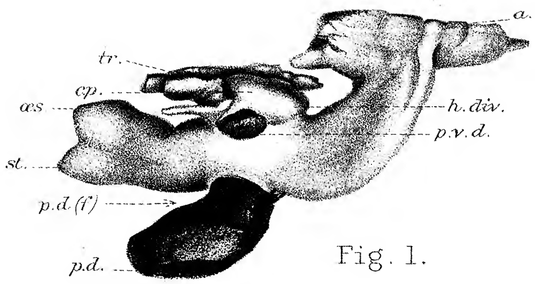


Fig. 1.

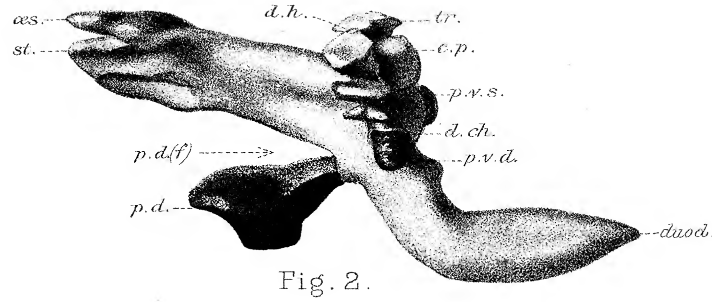


Fig. 2.

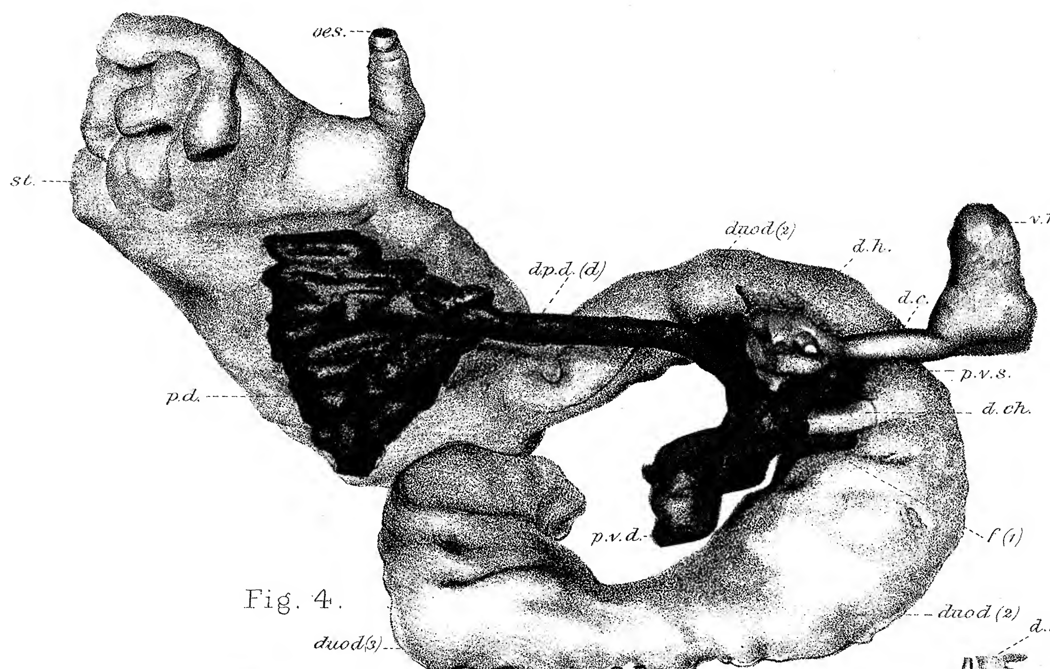


Fig. 4.

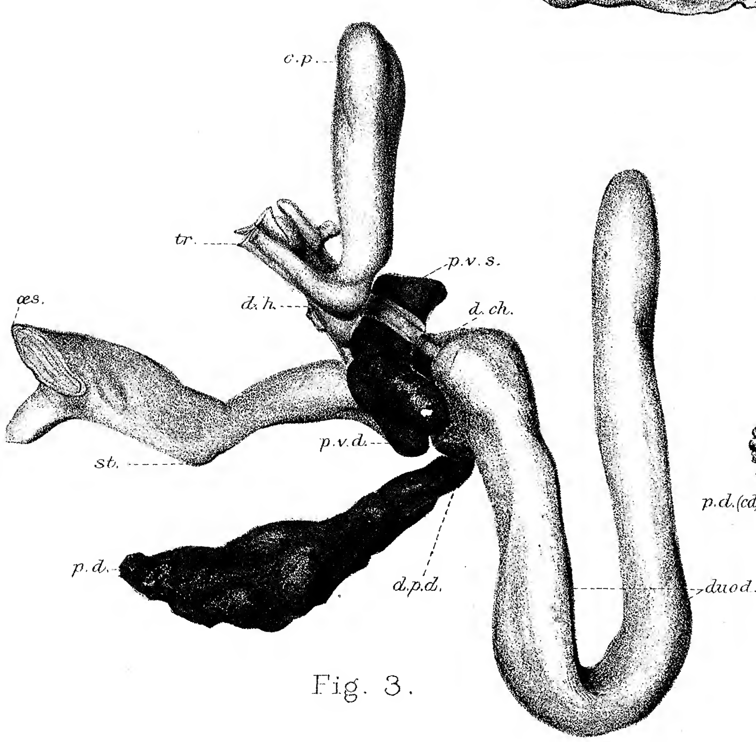


Fig. 3.

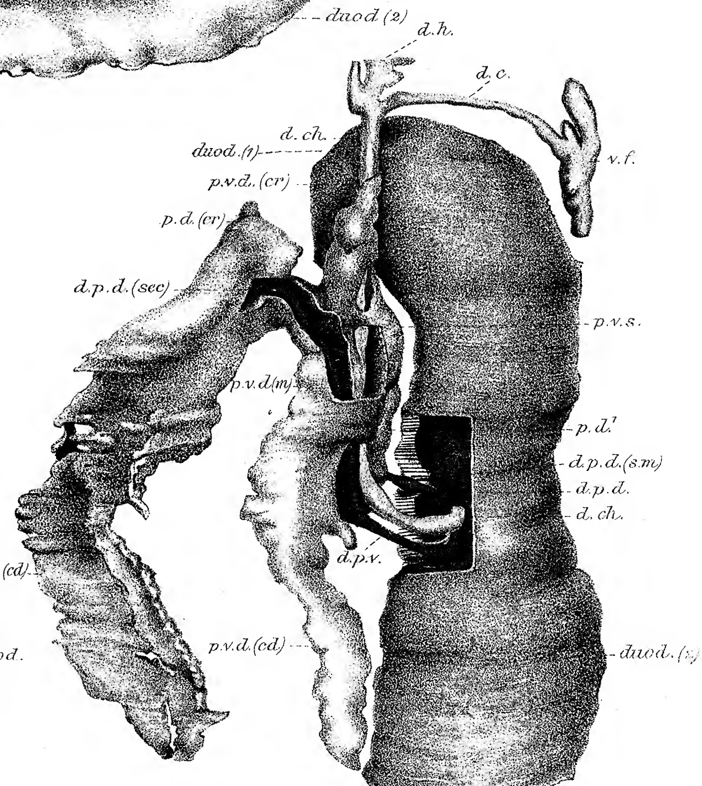


Fig. 5.

E. A. Steele del. Huth, Lith[r] London.

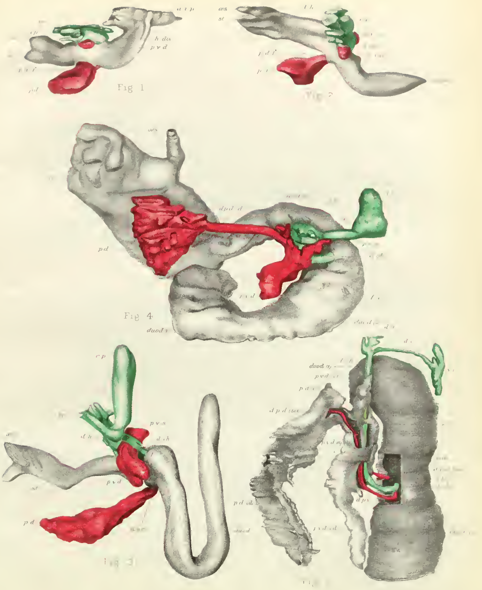


PLATE 11.

Fig. 1.—Stage II (embryo γ'99, G.L. 5 mm.). Right lateral view of model, showing the dorsal pancreas and the hepato-pancreatic complex. There is no left ventral pancreas at this stage. The aperture of the dorsal pancreas is dorsal, that of the hepatic diverticulum is directly opposite and ventral in position. $\times 50$.

Fig. 2.—Stage III (embryo α'97, G.L. 7 mm.). Right lateral view of model. The left ventral pancreas is now present in addition to the right. The apertures of the dorsal pancreas and hepatic diverticulum have retained their primary positions. $\times 50$.

Fig. 3.—Stage VIII (embryo XII A'02, G.L. 7·25 mm.). Right lateral view of model. The aperture of the ductus choledochus has shifted its position through 60° and now opens laterally into the duodenum. $\times 50$.

Fig. 4.—Stage XI (embryo 4'99, G.L. 10·25 mm.). Right lateral view of model. Fusion has now occurred, resulting in a complete pancreatic ring surrounding the ductus. The ductus choledochus now opens dorso-laterally into the duodenum. No dorsal pancreatic duct is present here. $\times 50$.

Fig. 5.—Stage XX (Pouch-fœtus, G.L. 30 mm., H.L. 14 mm.). Right lateral view of model. The dorsal pancreatic duct and the ductus choledochus open dorso-laterally into the duodenum. A definitive ventral pancreatic duct is here present, in addition to which the secondary duct is recognisable. (Some pancreatic tissue and part of the wall of the gut have been removed to expose the ducts.) $\times 21$. *p.d.'*, caudal prolongation of the dorsal pancreas on the left of the ductus choledochus; *p.d.(cr.)*, cranial region of the dorsal pancreas; *p.d.(cd.)*, caudal region of the dorsal pancreas; *p.v.d.(cr.)*, cranial region of the right ventral pancreas; *p.v.d.(cd.)*, caudal region of the right ventral pancreas; *p.v.d.(m.)*, middle region of the right ventral pancreas.